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ABSTRACT

The National Science Teachers Association (NSTA) has assembled this collection of reprints to assist teachers in organizing a science fair, working with students and establishing equitable judging procedures. The NSTA position statement on science fairs is included. The 19 reprints in this volume are geared toward secondary school students and are organized into 4 sections following an introduction and general overview. Sections include: "Planning Ahead"; "The What, Why and How of Projects"; "A Fair Evaluation"; and "Beyond the Science Fair." Appendices include a project application, an information sheet, a project schedule, a scientific method record sheet, a note for parents, a list of judging criteria and a judging form. (CW)

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ED 291 564

SCIENCE FAIRS AND PROJECTS

GRADES 7-12

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National Science Teachers Association

SE 048 896

SCIENCE FAIRS AND PROJECTS

7-12

A Collection of Articles Reprinted From

Science and Children
Science Scope
The Science Teacher

NATIONAL SCIENCE TEACHERS ASSOCIATION

First Edition—1984
Second Edition—1985

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Introduction

Science fairs have become somewhat of an American tradition. For a brief time each year those familiar poster displays appear in classrooms and school gymnasiums across the nation, affording young scientists the opportunity to share their interests with parents, relatives, and neighbors. Erupting volcanoes, styrofoam planets, seashell collections, stop smoking posters, and gerbils in mazes stand next to experiments with plants and solar energy. They have become part of the tradition. For many students the science fair will be the culmination of hard work and persistent investigation; it may mean the beginning of a life-long fascination with science.

For me the fascination has continued. My student science project helped me to understand scientific methods and the joy one feels at the moment of discovery. As a teacher, I learned right along with my students in discovery after discovery. The rewards have always been there, and science projects became integral to my teaching of critical thinking and process skills.

Yet science projects and science fairs are not popular with everyone and with good reason. The science fair tradition includes unfair judging procedures, forced participation, and overzealous parental involvement. Poorly planned science fair activities have detracted from the science curriculum. Worst of all, some students have been discouraged by participating in science fairs.

So, what are the solutions? How can a teacher ensure a successful and rewarding science fair? Planning, of course, is essential. NSTA has assembled this collection of reprints from *Science and Children* and *The Science Teacher* to assist teachers in organizing a science fair, working with students, and establishing equitable judging procedures. Suggestions are offered for involving young children as well as high school students in projects appropriate to each. An open letter helps parents guide their children in selecting and carrying out investigations.

Keep in mind as you read through these articles that not all authors agree on the methods for organizing a science fair. Ultimately, you will have to decide what you hope to achieve, who will participate, how the fair will be organized, and how projects should be judged (if at all). Be assured that a successful fair requires much effort, but the rewards are everlasting. Wouldn't it be great to discover that one project this year has sparked a student's life-long fascination with science?

Barry A. VanDeman
Educational Services
Coordinator
Chicago Museum of Science
and Industry

NSTA Position Statement on Science Fairs

The National Science Teachers Association recognizes that many kinds of learning experiences, both in and beyond the classroom and laboratory, can contribute significantly to the education of students of science.

With respect to science fair activities, the Association takes the position that participation should be guided by the following principles: (1) student participation in science fairs should be voluntary; (2) emphasis should be placed on the learning experience rather than on competition; (3) participation in science fairs should not be made the basis for a course grade; (4) science fair activities should supplement other educational experiences and not jeopardize them; (5) the emphasis should be on scientific content and method; (6) the scientific part of the project must be the work of the student; (7) teacher Involvement in science fairs should be based upon teacher interest rather than on external pressures or administrative directives; and (8) if a science fair is to be undertaken, such an assignment should be a replacement for one of the teacher's current responsibilities, and not an additional duty.

The National Science Teachers Association's Position Statement on Science Fairs was approved by the NSTA Board of Directors in 1968. This position statement is intended as a guide, and does not reflect the whole range of interest of our members.

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The Nuts and Bolts of Science Fairs

Barry A. VanDeman
Philip C. Parfitt

The date for the science fair has been set. The auditorium has been booked. And you are the head of this project. Now what happens? Momentary panic, for one thing, but, when you recover from that, the questions take over. Who's going to answer them?

In fact, there are many sources of help, and the articles collected in this volume will point you toward some of them.

1. Is there more than one kind of science fair project?

Almost any science topic can be the basis for a science fair project. And the possible approaches are also numerous: models, collections, demonstrations, hobbies, and experiments are displayed each year at science fairs across the nation. Any of these approaches can help a student learn certain science content and science skills. What type or types you encourage (or allow) at your fair will depend on your science goals.

2. How can I help my students select science fair topics?

Perhaps the most difficult part of doing a science project is selecting a topic and, if necessary, formulating the question to be answered. Take some time to work with students early in the year. Introduce them to possible topics—and give them practice in asking useful questions. Juliana Texley (page 20) and Martin Teachworth (page 30) share thoughtful approaches to helping students select and design topics for investigation.

3. By what criteria should projects be judged?

That depends on the nature of the project. Each project should be judged by criteria specific to itself. Models, for instance, should not be judged by the criteria used to judge experiments. Several articles offer sound advice. See Bellipanni, Cotten, and Kirkwood, (page 38); Harvey Goodman (page 37); Eugene Chiappetta and Barbara Foots (page 34).

4. Should students be required to do science projects?

In general, students should not be required to do projects if competition and awards are part of the fair. Science projects should encourage students to explore areas of science they are interested in. Forcing them, at the same time, to compete with classmates can turn off the very interest in science that the fair is designed to encourage. When the fair is not competitive, projects might be a regular class assignment, used to teach science skills while allowing for student preferences.

5. Should students receive awards for projects?

This is up to you. Some teachers offer certificates of participation to all student exhibitors. Others give first, second, and third place ribbons or certificates. Still others award trophies to outstanding projects. We recommend that every student receive an award or acknowledgement of participation.

6. In what ways can the librarian help my students?

Librarians can offer lots of help if they are familiar with your standards for researching projects and writing reports. Several months before you send students out to do research, talk with the school librarian and the public librarian. Explain your science fair goals and suggest types of resources that will help your students do their projects. Marge Hagerty (page 15) offers suggestions to prepare librarians for the science fair season.

7. How can parents avoid offering too much help—or too little?

This is a common question and a big problem to which there is no easy solution. Some parents, in their desire to have their children do well in the competition, complete much of the project themselves. However, parents can play a more acceptable role if they limit their participation to guidance and support. Be sure to let parents know how they can assist by meeting with them or sending a letter home. See the appendix for a suggested letter to parents.

8. Students sometimes have a hard time using measurements accurately. How can I help them?

Unless they have specific direction, students often express measurements in qualitative terms. For example, they will say the plant got "bigger." Encourage your students to make quantitative observations—that is, to use numbers in measurements whenever possible. Encourage them, too, to use the metric system in making their measurements—all scientists do.

9. Can my students participate in state and national competitions?

Many states offer both regional and state science expositions. Other competitions, scholarship programs, talent searches, and awards are also available locally and nationally. The "Beyond the Science Fair" section includes information on a science super bowl and the National Science Olympiad, in addition to a competitions sampler.

10. How should I plan my science fair?

Planning a science fair requires much time and effort. Take some advice from those who have experience organizing fairs. See Brian E. Hanson (page 12); Barbara Tohm (page 10); Ruth Bombaugh (page 14).

Barry A. VanDeman is educational services coordinator at the Museum of Science and Industry, Chicago, and President of the Council for Elementary Science International; Philip C. Parfitt is education associate at the Museum of Science and Industry. Photograph by Barry VanDeman.

Further Science Fair Resources

Aldridge, Bill G., and Johnston, Karen L. (1984). Trends and issues in science education. In R. W. Bybee, J. Carlsen, and A. J. McCormack, (Eds.), *1984 NSTA yearbook: Redesigning science and technology education* (pp.31–44). Washington, DC: NSTA.

Loiry, William S. (1983). *Winning with science.* Sarasota, FL: Loiry Publishing House.

Rice, Jeannie Rae. (1983, January). A special science fair: LD children learn what they can do. S&C, 20(4), 15–16.

Safety in the elementary classroom. (1978). Washington, DC: NSTA.

Safety in the secondary classroom. (1985). Washington, DC: NSTA.

VanDeman, Barry A., and McDonald, Ed. (1980). Nuts and bolts science fair blueprint poster. Harwood Heights, IL: The Science Man Press.

Youden, W. J. (1985). *Experimentation and measurement.* Washington, DC: NSTA.

The following science trade books might also be useful to your students as they prepare their science fair projects.

Beller, Joel. (1982). *So you want to do a science project!* New York: Arco Publishing.

Gutnik, Martin J. (1980). *How to do a science project and report.* New York: Franklin Watts.

Moorman, Thomas. (1975). *How to make your science project scientific.* New York: Atheneum.

Smith, Norman F. (1982). *How fast do your oysters grow?* New York: Julian Messner.

Stepp, Ann. (1966). *Setting up a science project.* Englewood Cliffs, NJ: Prentice-Hall.

VanDeman, Barry A., and McDonald, Ed. (1980). *Nuts and bolts: A matter of fact guide to science fair projects.* Harwood Heights, IL: The Science Man Press.

Webster, David. (1974). *How to do a science project.* New York: Franklin Watts.

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Planning Ahead

A successful science fair takes plenty of time and energy—and organizing skills. Long-term planning and continued work throughout the year will help you overcome one of the biggest obstacles—finding time to take care of all of the details that add up. Start with a science fair master schedule that will help you find the time to reserve the space, pick judges, line up parent volunteers, prepare students, alert the media, and give it your all!

Mission Possible: The Science Fair

by Barbara Tohm

Mysterious music. Stage lights soft. Teacher enters, stage right. Turns on tape recorder: "Your assignment, should you choose to accept it, will be to organize and conduct a science fair at your school." Teacher removes papers and photos from an envelope. "You may contact these support agents at any time in your mission." Photos are of local scientists and art, mathematics, science, and graphics teachers. "Good luck." Music down. Lights up. Teacher goes off on her mission, stage left.

• • •

Planning a high school science fair strikes some of us as a bit masochistic. But if you think of the effort as a major campaign to increase student skills and to have fun with science, the task is worth the pain and time. Long-range planning is important, however, because the details add up. Here's how I've survived my mission.

Start your planning on the first work day of school. Teach the scientific method from day one. During the stage for picking topics, allow time in your schedule for students changing their minds a hundred times. Map out at least 4 days in the library at the outset: The first 2 days should be early in the year, the third about a month before the fair, and the last right before the deadline. I keep alternate library assignments dealing with scientific research ready for any students who tell me they have finished early or that our school library does not have anything they need.

Check the date of the county or regional fair before you set your own deadlines. Allow a few weeks between your school's fair and the county or regional fair so students can polish their presentations or collect more information.

Select one tentative date and at least one alternate date before making an appointment with the principal and the activities director. Schedule the fair at a time that won't conflict with any major sporting events or meetings that take the science teachers out of the building.

Check with the person in charge of the room you hope to use. Each year the amount of space we require grows. Find an area of your school that will be flexible. We hold our science fair in the library. You can always adjust for fewer projects, but it's tough to make more space in tight quarters.

Prepare and duplicate written requirements and specifications. Go by the county or regional science fair rules and guidelines as much as possible, to avoid conflicts in case students want to go on in competition. Set firm deadlines and stick to them.

Distribute two copies of everything you prepare to every science teacher in the school. This way each teacher has a set to keep and a set to send for copying. It is important for teachers to make lots of extra copies, since students will be sure to lose theirs during the weeks before the fair.

The scientific method

Stress the scientific method throughout the fall. Students have a difficult time working with experimental design, setting up a control, identifying independent and dependent variables, and assembling the components of a good experiment. Allow room in your lesson plans for many miniexperiments in the laboratory—not just exercises but also opportunities for students to plan their own procedures and to collect data themselves. Many lab exercises provide practice in technique only. Your students will need more experience in real decision making before they can conduct their own science experiments.

Invite local scientists to your class to describe real research. Research centers and industry can often provide speakers and films. Encourage students to write letters and to contact professionals themselves.

Science fairs teach students how to

Sandy Goodman

Robby Goodman, first-place winner in his school science fair and in the Dade County science fair for his project, "The Effects of Fusarium Oxysporum f.s. Lycopesici on Various Garden Plants."

think on their own, but coming up with ideas is always difficult. Students can brainstorm and review the previous years' fair entries for starters. Suggest they come up with a different way to do something that has already been done—this challenge to "beat the system" often fires up apathetic adolescents. A small percentage will never come up with a problem, perhaps because they refuse to think. When the deadline nears, I offer these students a ready-made problem for a "C" grade; I offer the chance for a "B" if they make a significant improvement on my suggestion and an "A" if they make improvements and an oral presentation to the class.

Time becomes the biggest obstacle to running a successful science fair. Planning time, teaching time, building time, research time, display time—and perhaps the hardest to find, grading time. The grading must fit into the slot between the school fair and the regional fair. But no matter how carefully I plan, time runs out too soon.

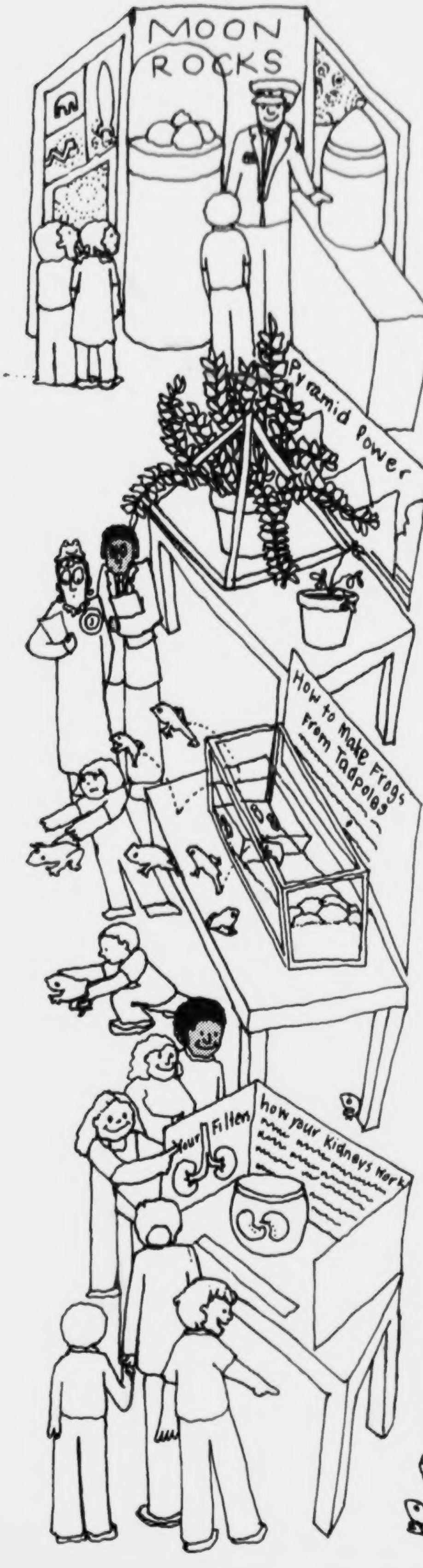
Ask for help from other departments. The art department at our school provides posters and category signs. Woodworking students make backboards. (Ordering materials in large quantities saves students money and time.) The math department draws maps of the library and works out possible room arrangements dependent on the number of displays, and the advanced science students set up and take down the fair. English teachers help us teach research skills; some even count the written portion of the project for a grade.

Each year I learn something that makes the schedule a bit easier. I schedule the fair during the final week of first semester because the library is closed to students then. We also have time that week for science students, when they're not taking exams, to view the projects. When they visit, students complete a worksheet so I know they've paid attention to the work. Admission tickets help us control the number of students who enter the fair area at one time. Be sure to protect the projects from vandalism during visiting time; the science club might volunteer for this duty.

Too many is not enough when it comes to judges. Ask judges early for their help, and expect someone to cancel out at the last minute. Send out a letter the week before the fair to remind the judges of their commitment, and ask their preference for time. I even call them on the eve of the fair for a final reminder. Judges, who are often scientists themselves, get excited about what students are doing and provide great public relations when they return to the community.

New this year is our Science Board, made up of past winners at each grade level, which advises novices. I would like to see clinics established to help students develop their ideas with the aid of others who have been there before. Each year is a growing experience, and my goal is to have students organize the fair themselves with little help from me. In the meantime, I continue to view the science fair as a "Mission Possible."

Barbara Tohm is a science teacher at South Dade Senior High School, 28401 S.W. 167 St., Homestead, FL 33030.



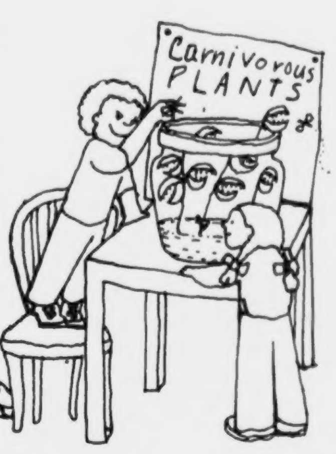
Planning a Fair with a Flair

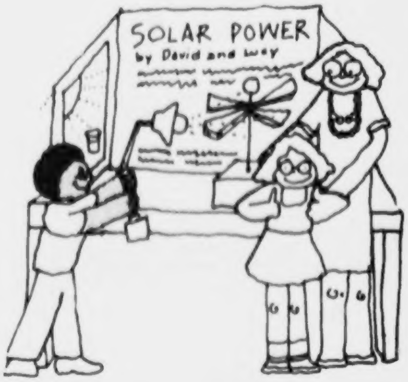
Brian E. Hansen

Though a successful science fair requires an enormous amount of time and energy, the payoffs are impressive: students get excited, parents become involved, and school-community relations are improved as the community is invited to take part in making the fair a success. That, anyway, is what we found when Sugarland Elementary School in Sterling, Virginia, held a fair last spring. More than 40 student science projects were exhibited, along with classroom science work from each class and seven professional and commercial science displays. Over 400 children and adults attended the fair. Planning, of course, was the key to its success.

First Steps

Sugarland's Science Fair Committee consisted of five volunteers—three parents and two teachers—who had expressed an interest in the school's science program. The committee began holding monthly meetings in October, about five months before the March date set for the fair. Working backward from that date, they established a schedule that allowed them to complete preliminary planning in about three months. (The two additional months would allow students time to work on their projects.) They began work by drafting the rules for the competition, the entry form, lists of suggested topics, and a cover letter. The rules included the entry and project completion dates, size speci-





fications for the final display, and judging guidelines. An important part of the rules was a statement that distinguished between a scientific experiment and an encyclopedia report and encouraged students to stay away from the latter. The entry form asked that the student describe the hypothesis, methods, and equipment for the proposed project, and it also called for a parent's signature to indicate permission for the student to participate in the fair. Suggested topics were drawn from the students' science texts, with one list for first, second, and third grades and a second list for third, fourth, and fifth grades. When all the entries were in, the committee checked to make sure the forms were complete and the proposed projects practical and safe. (No bombs or erupting volcanoes, please.) Several students chose identical topics, but this caused no difficulty since the finished projects proved to be remarkably different.

On with the Projects

To make sure that students (rather than parents) did the projects, Sugarland's committee required that all work be done at school. To make this possible, they arranged to keep the cafeteria open after school two days a week for half an hour each day. A Science Fair Committee member and parent and teacher volunteers supervised the students and took attendance to find out which students needed reminding to work on their projects. (No matter what the hypothesis, if a student abandons his or her plants in the storage room for four weeks without water, they will die.) During the rest of the week the student projects were stored in an unused classroom. For the next science fair, the committee intends to add extra after-school work sessions during the crucial first and final weeks. It will also offer additional help for younger students. (One first grader cried when her project didn't work the way she thought it was supposed to.)

Getting the Word Out

The committee member in charge of publicity really had two jobs: he needed to stir up school enthusiasm, and he needed to let the community know about the fair. The school menu and the parent/teacher newsletter were useful in publicizing the fair and its entry deadline among students and their parents. The committee also aroused interest in the fair by sponsoring a school-wide contest to pick a cover design for the program. Extramural publicity was provided by local newspapers, which were contacted both when the fair was originally announced and again a few weeks before Fair Night, with information about the date, time, and place and an invitation to send photographer-reporters to cover the fair.

The Community Participates

Sugarland encouraged community involvement in the fair by inviting scientists and science-related businesses in the area to set up displays of their work and products.

Science Fair Checklist

____ Recruit five to seven volunteers (teachers *and* parents) who have good organizational skills and an interest in science to serve on the Science Fair Committee.

____ Set time and date of fair about five months after first committee meeting. (Clear date with principal.)

____ Draft science fair rules (entry deadline, size limits for display, requirements for final report and log of observations, completion deadline, judging guidelines). Emphasize requirement that all work be done by students. Urge experiments rather than reports.

____ Design entry form (name, project title, hypothesis, method, materials, places for student and parent signatures).

____ Make up lists of suggested topics. Check with teachers, librarian, and science texts for ideas. Have separate lists for upper and lower grades.

____ Draft cover letter from principal introducing fair and explaining rules and schedule of after-school work sessions.

____ Design final report form (student number, project title, grade, hypothesis, method, summary of observations, conclusions). Don't leave space for student's name because projects are to be judged anonymously.

____ Design judges' evaluation form (number and title of project by grade, boxes for scores in each category).

____ Organize school-wide contest to select cover design for program.

____ Ask teachers to save their students' classroom science work to display.

____ Locate and reserve a vacant classroom where students can work on and store their projects. Projects need to be locked up between work sessions.

____ Schedule parent and teacher volunteers to supervise the after-school work sessions.

____ Publicize (1)application deadline, (2)science fair night, and, after the fair has taken place, (3) the winners.

____ Find judges (high school and college science teachers, district science supervisors, professional scientists).

____ Find commercial exhibitors and professional science demonstrators.

____ Solicit prizes or contributions to buy prizes.

____ Order ribbons and certificates for participating students. (Some companies will print the event and school's name on them.)

____ Arrange buffet for judges and demonstrators who may work through dinner before the fair opens.

____ Plan and type the science fair program.

____ Plan arrangement of booths to allow plenty of room for spectators.

____ After the fair is over, send thank-you notes to parent and teacher volunteers, judges, and demonstrators.

Brian E. Hansen is an associate professor of English at the Loudoun Campus of Northern Virginia Community College, Sterling, and he served as secretary of the Sugarland Elementary School Science Fair Committee in 1981–82. Photograph by Ruth Larsen, Loudoun Times-Mirror. *Artwork by Marilyn Kaufman.*

INVESTIGATING PITCH
PROBLEM
HYPOTHESIS
MATERIALS
PROCEDURE
DATA
CONCLUSION
PROBLEM
102

—William Mills, courtesy of Montgomery Co. Public Schools, Md.

(Here was an additional area in which parents were an important resource.) These contributions, which were a big success, included moon rocks and a model of the Space Shuttle provided by the National Aeronautics and Space Administration and the telephone company's laser equipment. Visitors could operate broadcast equipment from a television station or inspect a sound truck belonging to a radio station, examine home computers lent by a local business or a microscope and slides supplied by a medical laboratory technician.

Judging

Each class had a display of the science work that students had done during the year. These displays allowed students to take part in the fair in a noncompetitive way. It also drew additional parents on science fair night. Judging the more than 40 projects entered in competition was done by a nine-person panel selected by the Science Fair Committee and composed of college science teachers, scientists, and science supervisors in the school system. Parents of students in the school were not eligible to serve on the panel. The criteria used had been adapted from those of Science Fairs International,* and they were weighted to reward experimentation rather than mere neatness, as follows:

Creative ability	35
Scientific thought	35
Thoroughness	20
Neatness	10
	100

Each judge worked independently to evaluate all the projects for one or two grades, recording scores on a sheet listing project titles but not student names; and each project was evaluated by three or four judges. First and second prizes and honorable mentions in each grade were conferred according to the total points awarded by judges, who based their evaluation on a student's table display, including the equipment used, final report (hypothesis, method, summary of observations, conclusions); log of observations; and, frequently, a posterboard explanation.

What About the Prizes?

The prizes were donated by local merchants or purchased with money from parent/teacher organization funds. (The committee tried to interest national chain stores in contributing prizes by contacting both their local outlets and their headquarters but had no luck.) First- and second-place winners were presented with a certificate and an award—for example, a globe, book, or scientific model. Those who earned honorable mention received a certificate and a pamphlet about the space program. Each entrant got a blue ribbon.

Last-minute Details

After lunch on the day of the fair, several volunteers and the Science Fair Committee chairman arranged the tables in the cafeteria. They grouped the tables for the competitive science projects by grade level in the center of the room and the ones for the classroom science work and the professional-commercial demonstrations around the walls. Right after school, students set up their science projects, and teachers brought in their classes' science work. The judges began evaluating the projects at 5 P.M. and the businessmen, technicians, and scientists setting up their displays at 5:30 P.M.. By 7 P.M., with the judging and preparations complete, everyone got a chance to eat a buffet dinner of sandwiches, salads, coffee, and soft drinks provided by the parent/teacher organization. The fair began at 7:30 P.M. with a ten-minute program consisting of thanks to the parents and teachers who had worked on the fair and the presenting of prizes and certificates to the winning students. Then, for the next hour and a half the Science Fair Committee got *their* prize—they watched 400 students and parents enjoy the fair.

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*Write Science Service, National Science Fair International, 1719 N St., N.W., Washington, DC 20036.

Other Sources of Information

AIRPORTS

If your project deals with aeronautics, an airport is a logical place to locate information. Airports often employ meteorologists that may help with projects dealing with the weather.

ANIMAL HOSPITALS

Often, veterinarians are willing to help with science projects. If you request help, call several weeks in advance for an appointment.

BOTANICAL GARDENS

Plant specialists can be found at botanical gardens. Maybe your community has a Garden Club with members who know about plants.

COLLEGES AND UNIVERSITIES

Colleges and universities have more than one thing to offer. Their libraries will probably offer a wider selection of references than a local library. Scientists on the faculty may help you and even allow the use of their laboratory facilities.

GOVERNMENT AGENCIES

Government agencies are usually listed under "Federal," "State," and "Munincipal" categories in the telephone book.

The United States Government Printing Office is also an excellent resource. Send a letter indicating what topic area you are interested in and they will send a catalog of available books and pamphlets. The address is U.S. G. P. O., Superintendent of Documents, Washington, D.C. 20402

HOSPITALS

Many hospitals have an education department you can contact. Perhaps your physician, dentist, or eye doctor can also give you help.

INDUSTRIES

Major industries often have specialists who may be willing to help. Try locating them with the telephone book or magazine advertisements. When writing to corporations, include "Public Relations Department," in the addressing of the envelope and letter.

NATURE CENTERS

Naturalists at nature centers might be able to give information if your project involves natural environments and ecosystems. The Audubon Society can direct you to nature centers and evironmental centers throughout the United States.

TELEPHONE BOOKS

The Yellow Pages of a telephone book, will list names, addresses, and general product information. When calling anyone, remember to be polite. Give your name and tell exactly why you are calling.

ZOOS

Most major cities have zoos, and most have education departments or zoological societies that may be able to help. They may be able to arrange a meeting with an animal keeper or zoologist. A visit to the zoo may also help you decide on a topic.

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The Library Can Help

To the young scientist preparing for a science fair, libraries offer a wealth of inspiration and information.

Here is a list of ways libraries can help with school science fairs; explore them with your librarian and principal.

Update your collection of science titles. Ask the librarian to show you the science shelves or shelf list. Then suggest, by subject or title, books and periodicals needed. Offer to help weed the collection of obsolete material. Just an hour of your expertise could make a difference.

Contribute to the library's vertical file of clippings and pamphlets on science subjects when you can. Suggest subjects for new files which could help students with science projects.

Does the library offer students help with scientific inquiry—with making projects scientific? Consider acquiring some good books and filmstrips on the scientific process.

Above all, be sure you know how to check out different media and equipment. Can you locate items by subject? Can your students?

- *Establish special circulation rules preceding the science fair.* To avoid chaos and allow ample access to useful materials, ask the librarian to set special circulation rules for the weeks prior to the fair. Books dealing with physical science experiments might be reserved for two-day checkout, one per student. Or, arrange these books on a work table in the library, not to be checked out at all before the fair.

- *Set special study schedules.* Just before the science fair, the library might reserve more time for independent study or for entire classes to research projects under their teacher's guidance. Ask parents to help during these times.

- *Offer an in-service library session for teachers.* Before introducing the science fair to students, arrange a library session for teachers. The librarian can review the range and location of science materials, show pictures or slides of past fair projects, and discuss library rules and processes.

- *Introduce or review library and study skills.* Students will be motivated to learn these skills when they need them to complete projects. Just before the students begin their research, review the use of the card catalog and media listing, emphasizing science reference book sections. Discuss the Dewey Decimal System—especially 500s and 600s (pure science and applied science).

- *Record projects in progress.* The librarian can list in a prominent place all the science projects in progress and the names of students working on each. The recognition could induce reluctant students to participate. List projects by general subject and Dewey Decimal numbers, e.g., *Projects on Magnetism 538.* The list will indicate when to stop restricted checkouts and order additional materials.

- *Correlate science and language arts.* As the science fair approaches, the librarian can arrange presentations to students to include materials related to science subjects. What better time for using nature poetry and haiku for example, than when students are working on nature experiments?

The librarian might invite students who are participating in the science fair to write short science fiction stories. Such activities offer a break from working on projects while building students' interest in science.

- *Offer science centers.* Set up science interest centers during the fair or before. Assign responsible students to help prepare these. Each center should present an investigation for students to perform, provide materials necessary for the job, and suggest means for evaluating results.

- *Display winning works.* Students learn more from others' projects if they have plenty of time to examine the experiments. So, after the fair, honor the winners by displaying their projects in the library media center.

—Marge Hagerty, Librarian
Chinn Elementary School
Kansas City, Missouri

MASTERING the SCIENCE FAIR

Do you feel overwhelmed by details at the very thought of a science fair? You don't have to. Use this master schedule as your checklist, and spread those tasks out over a year's time.

I've been perfecting this schedule for about ten years, so I know it works. I began to develop it because as a young teacher I was a lot like my seventh-grade students—long on energy and enthusiasm, but short on organizational skills. The details became unmanageable.

Even a seemingly innocuous detail like arranging space for the fair can cause big problems if it's not attended to far enough in advance. The first science fair I organized was elbow-to-elbow with 180 students packed into the cafeteria. Now I reserve the gym a full year ahead of time.

I start by going over the basketball schedule with the athletic director to make sure the gym is free, and my seventh graders aren't scheduled for an away game on the night I want. Next I explain to the gym teacher that we'll need to set up on the day of the fair, and offer to trade spaces with her for that one day. Finally, when I've gained the cooperation of both the athletic director and the physical education teacher, I go to the principal and make a building request in writing. I also reserve the cafeteria as a hospitality area for the evening of the fair. This gives parents a place to be while the judging is going on.

Preparations inside the classroom also begin a year in advance. Each spring, I visit the various sixth-grade classes to tell them about the science fair. This gives the students lots of time to start thinking about science projects. I bring some of my most successful seventh graders along to demonstrate their projects. I share our "brag book" of pictures, newspaper clippings, and other evidence of the recognition my students have won at district and state fairs. This introduction to the science fair stirs up enthusiasm and anticipation.

The next fall, I give the students experiences with hands-on labwork. They learn the scientific method by performing controlled experiments. The students practice for the fair by writing up several of their experiments as formal summaries, including question, hypothesis, materials, procedures, results in a chart or graph form, and a conclusion.

Early fall is also the time to draft a schedule specifying the minimal requirements for the science fair and setting a due date for each requirement. The six requirements are: (1) performance of an experiment with data collection, (2) a formal summary of the experiment, (3) a research report with bibliography, (4) a visual backdrop, (5) an oral presentation, and (6) attendance on the night of the fair.

Structure is vital to the success of the fair. The schedule of steps and due dates provides the solid framework middle school students need. A number of my "learning disabled" students have won high honors at district fairs thanks to the structure the ten-week student schedule gave them.

Communication between home and school is another vital element to planning a science fair. At the first parent/teacher conference, I give parents a copy of the schedule and a letter that fills in the details. Parents are consistently supportive when they know what will be expected of their children.

Students spend three of the total ten weeks deciding on a project. Choosing the right project is the most essential step of the whole process. I don't want any student to work on a project which is so undemanding he or she won't learn from it, but I also don't want projects so difficult that students are set up for failure. Most seventh graders have never had to make choices of this kind before, so they need patient guidance.

To be fair to the students, judging criteria are based on the requirements they have been asked to meet. I give copies of the judging sheets to students well in advance so they know how their projects will be rated. They will earn 45 of the 100 possible points just for meeting the basic requirements. Knowing this motivates them to keep on schedule. The remaining 55 are quality points which indicate how well they meet the requirements.

When science fair day finally arrives, I can relax and enjoy myself. It's like a wonderful party! Students are dressed up and on their best behavior. The gymnasium has a holiday air. I make sure that I am free to greet the judges, who are local professional people. I put a high premium on student/scientist interaction. I don't assign judges more than four to six projects each. Students spend a class period after the fair writing personal thank-you notes. As a result, judges are eager to keep coming back year after year.

After the school fair, the students designated to go to the district fair get together to further improve their projects. Again, structure and communication are essential, so I arrange a time after school for each student and a parent to meet with me, read the judges' comments, and draw up a contract for the tasks the student agrees to do as part of our school's science team. These tasks include preparing the oral presentation for videotaping and practicing it in front of the sixth-grade classes when I make my spring visits. This completes the yearly cycle which began the previous spring.

RUTH BOMBAUGH
Langston Middle School
Oberlin, Ohio

Master Schedule for Director of the Fair

During the School Year Previous to the Fair

Preparation Outside the Classroom

Reserve the gymnasium for the whole day of your fair. (Talk to athletic director, gym teacher, principal.)

Reserve the cafeteria as a hospitality center for the evening of your fair.

Urge fellow teachers to assign your prospective students a research report.

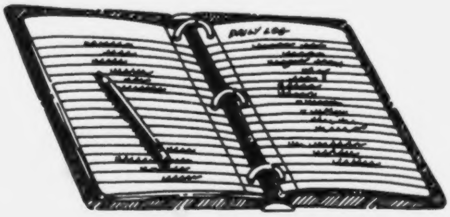
Plan the format of your fair with the other teachers who teach the same grade. Possible options include:
1) An Interdisciplinary Science Fair: all students do a science project but the library research is a social studies assignment, the backdrop is an art assignment, the graphs are a math assignment, etc.
2) An Academic Fair: all the teachers cooperate, and students may choose to do either a math, social studies, science, or language arts project.
3)A Science Fair only the science teacher oversees.

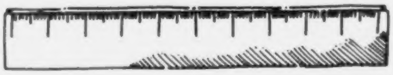
Preparation Inside the Classroom

Visit the science classes to tell all prospective students about the science fair.

Schedule the current science team to give presentations to the prospective students and display their finished products.

Help any interested students to design science fair projects which they can work on during the summer.





Before Students Start to Work on Their Science Fair Projects

Preparation Outside the Classroom

Prepare letter for parents which states requirements that students must meet.

Prepare week-by-week schedule for students telling what they should be working on and what deadlines they should meet.

Prepare judging sheets.

Prepare award certificates and order ribbons. (Any student calligraphers ?)

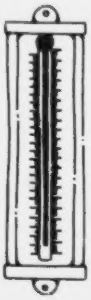
Reserve public library and school library time for students to be shown reference materials. Arrange to have reference materials in the classroom too.

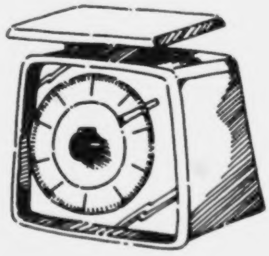
Reserve space and time for awards assembly.

Preparation Inside the Classroom

Stress hands-on lab experiences with data collection in your science classes. This reinforces concepts and helps students learn the scientific method in a concrete manner.

Require students to write up their lab experiments in science fair form. Make sure they have all the parts of an experimental summary—question, hypothesis, materials, procedures, results in a chart or graph form, and a conclusion.





During Student Preparation of Science Fair

Preparation Outside the Classroom

Contact resource people when they are needed for assistance.

Two to three weeks before the fair, line up your judges. (Personal contact by telephone works best.)

Preparation Inside the Classroom

Give it your all!

Follow the week-by-week schedule, and anticipate students' need to learn new skills. Teach how to write bibliographies about a week before they're due.

In the Ten Days Leading Up to the Fair

Preparation Outside the Classroom

Arrange hospitality. (Your school secretary, principal and/or fellow teachers may be willing to be hosts. Could the home economics students bake cookies?)

Make up the judging assignments and group sheets for each judge.

Make up name tags for the judges.

Arrange to have a volunteer photographer.

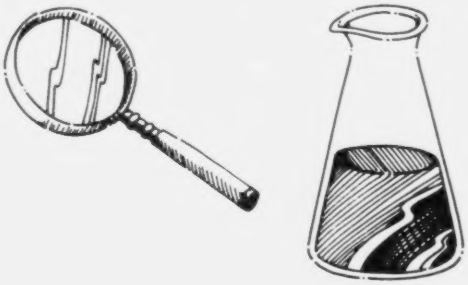
Alert the media (newspapers, radio, local TV).

Set up the tables and a microphone the evening before the fair.

Preparation Inside the Classroom

Continue to follow the week-by-week schedule and DON'T PANIC. The Last-minute Lizzies will often do wonders when the time crunch is on!

Go over the judging sheets in class and have students fill out the tops: name, date, title, number of project.



On the Actual Day of the Fair

During the School Day

Have students set up their projects during the class periods.

Let other grades view the projects, with your students serving as hosts.

Remind students to dress well for the fair and to be polite.

During the Fair in the Evening

Be sure you have delegated as much responsibility as possible. This involves more people in the fair and leaves you free to trouble-shoot.

Greet your judges! (They are V.I.P.'s.)

Enjoy yourself!

After the Fair

Finishing Up Local Fair

Average the judges' scores.

Fill in names on award certificates and host awards assembly.

Write articles for the newspapers.

Have students write thank-you notes to judges.

Preparation for District Fair

Draw together a science team of student volunteers and meet with each parent and student to draw up a contract of responsibilities.

Help each student follow through on his/her contract.

Videotape the science team.

The What, Why, and How of Projects

A science project should begin with curiosity and foster wonder. The best projects stretch students' investigative skills: questioning the world, wondering how it works, and delighting in and coming to understand its mysteries. But most students have little or no experience in the art of doing science. Use this section to help your students come up with project ideas. You can teach students how to design and to carry out projects and to think like scientists.

How To Create Problems

Coming up with a suitable research topic is tough. Make it easier with this reliable approach.

by Juliana Texley

High schoolers have little or no experience in the art of doing science. The most critical part of research—generating a problem that can be investigated—is far beyond their reach without guidance and training. How often have you suggested elegant schemes for student investigation, only to be met with "Can I play music to plants?"

Many of the winners of the Westinghouse Science Talent Search and other competitions work in tandem with researchers; that fact alone daunts many of us who hope to guide our students in the same direction. But most curricula can encompass research skills and a framework for coming up with project ideas and designs. Problem generation does not have to be serendipitous. You can teach it, as you can teach other process skills.

The second year

At Richmond High School, we restructured the second-year biology class to emphasize individual research. As we covered topics in anatomy and botany, we wove an unbroken thread of research methodology throughout the year. In this school, the first-year biology program covered so much in so little time that it didn't allow for research. The second-year course was the ideal place to start learning how to do independent investigations.

During September each class begins with "idea time." From a file of clippings and journals, I read hypotheses and abstracts that catch my eye. (We often use Science Briefs from *TST*.) For each topic, we discuss the student research possibilities, using a modification of a system known to educational researchers as Campbell and Stanley designs [1]. We were guided by the following questions: "What is the best way to investigate this topic?" "What equipment (or subjects) would we need?" and "What are the major potential sources of error (invalidity)?" Students never take long to catch on.

One-shot research

Figure 1 shows five experimental designs. T indicates one test or trial of an experiment, and X is a treatment. Time passes from left to right. This simple system (not too different from the diagram of a football play, according to my class) applies to all types of experiments in the Campbell and Stanley system.

In Figure 1a, often dubbed the one-shot pretest/posttest, one group or subject was tested, exposed to a treatment, and then tested again. Although this scheme is a poor one in the life and social sciences (it has no control, and observations on one organism cannot be generalized to others), it can sometimes be relatively meaningful in the physical sciences. The following

—Gail Rebhan

In the days b.c. (before computer), such designs were difficult for students to analyze. It is hard to convince young scientists that they can compound their errors by relying on the streams of decimals on their VDTs and calculators.

projects fit the experimental design:

- How does blanching affect the activity of enzymes in vegetables?
- How does adding a mordant affect the action of a fabric dye?
- How does stress affect the strength of a given plastic?
- How would adding a barrier of foliage affect sound transmission?

If you have a microcomputer, you can measure the results of these types of experiments relatively accurately by interfacing laboratory equipment. But this design is very limited. You can quantify "one-shot" experiments, but usually only with a histogram. While histograms are the most common way to display data in most science fairs, they are only a rudimentary tool. The key danger in an experiment of this design is overconfidence. One trial is seldom enough to draw any sort of conclusion in science—and it seldom takes students long to recognize this fact with the help of diagrams.

Controlling the problem

The randomized control group design is the standard for student project work in biology. (See Figure 1b.) With it, students compare the pretest (or initial condition) and the posttest (or final condition) with a control group. In its simplest form, this design provides data for the Students t-test (to determine the difference between sample means) or for chi-square analysis (for data in frequency form). The distinction between discrete and continuous data (and between histograms and line graphs) requires a great deal of class time. (In most math books students are taught to make both types of graphs, but they are never taught when to use each.) By contrast, students can figure out that the reliability of a randomized control group test depends on the number of subjects in the experiment.

As my classes discuss projects that are suitable for this design, we carefully define *random* and *control.* This is difficult because many students do not know how to isolate variables, and we have to stop to sort out the confusion.

Here are some examples of randomized control group experiments:

- How does electromagnetic radiation affect the orientation and flight of honeybees?
- How does calcium affect geotropism in plants?
- How does noise (interference) affect short-term memory?

Varying variables

You can strengthen designs such as those above if you apply the variable in a series of strengths, durations, or forms. (See Figure 1c.) Try some of these examples:

- What is the relationship between the concentration of fertilizer and the growth of plants?
- What is the relationship between the type of metal bowl and the stiffness of egg whites beaten within it?
- How does the wavelength of light

Figure 1. Campbell and Stanley experimental designs. T = one test or trial; X = a treatment.

a) one-shot pretest/posttest								
	T_1				X			T_2
b) randomized control group								
	T_1				X			T_2
	T_1							T_2
c) variable in a series								
	T_1				X_a			T_2
	T_1				X_b			T_2
	T_1							T_2
d) observations over time								
	T_1	T_2	T_3	T_4	X	T_5	T_6	T_7
e) progressive change								
	T_1	T_2	T_3	T_4	X	T_5	T_6	T_7
	T_1	T_2	T_3	T_4		T_5	T_6	T_7

Juliana Texley, the editor of The Science Teacher, *formerly taught biology at Richmond High School, Richmond, Michigan. At present, she heads the science department at University-Liggett School, 1045 Cook Rd., Grosse Pointe, MI 48236.*

affect seed germination?

- How does relative humidity affect plant growth or the sex ratios of invertebrate offspring?

In the days b.c. (before computer), such designs were difficult for students to analyze. It is hard to convince young scientists that they can compound the errors of their observations by relying on the streams of decimals pumped out on their VDTs and calculators. So we pause again to take a practical look at significant figures and why we need them.

Today most micros can perform a relatively straightforward statistical technique called analysis of variance. As the need arises in our discussion of experimental design, I explain the significance (but not the mathematics) of each statistical method, deliberately adding the terms *statistically significant* and *one-to-one correspondence* so that students will not forget the meaning (if not the method) behind each technique.

The end product of most of this research is a formal paper and publication of an abstract in our high school* Journal of Science*, a booklet that serves not only as a source of pride but also as a reference for next year's apprentice scientists.

From beginning to end

In biology, observations over time are often more valuable than single tests. The Campbell and Stanley design for this type of experiment is shown in Figure 1d. Students might investigate changes in the pH of egg white as an egg ages, changes in the reflex rate of animals as they age, or changes in the oxygen production by algae over time (biorhythms). When they inject a treatment into a time series, students often must rely on a computer for curve fitting and extrapolation. This is especially important when a student has a practice effect to take into account. For example, one of my students decided to test the question "Do video games increase hand-eye coordination?" But first, she had to determine the expected improvement caused by practice and then compare it to any significant experimental effect.

The final Campbell and Stanley design allows you to compare progressive changes in a subject over time to a control. (See Figure 1e.) This setup might represent such research as "Do neuroinhibitors affect metamorphosis in insects?" or "Can variations in the growth rings in fish scales (or trees) be correlated with specific environmental events?"

Now, it's my turn

As the class discusses each hypothesis or abstract and develops the appropriate design for an experiment, I ask students to think of potential sources of error and variations on the theme of the experiment. (Although we do not use a text, many books on research methods look very thoroughly at discussions of the sources of invalidity associated with each design [1].)

After a week or so, students begin to bring in their own clippings and ideas. We sometimes construct a "Tear and Share" bulletin board. Naturally, not all ideas fit into one or more of the Campbell and Stanley designs, so often we improvise and devise our own symbols. Our collection is sometimes raided, but students usually settle on ideas of their own.

After a month, students narrow down their field of research and contact a researcher who can answer their questions. The majority receive gracious responses, reprints, and sage advice. Some students move on to library research, and by November each student has a problem to concentrate on. Most problems are unique enough to keep both student and teacher intrigued for a few months.

Knowing full well that the majority of these teens are poor time managers, I always break up the research project into small units (problem, bibliography, procedure, materials collection, and so on) and enforce firm deadlines. Every year I have several well-intentioned procrastinators who miss their mark, as well as some who are determined to find nothing of interest.

But, in retrospect, this system has proved overwhelmingly successful. Many students carry their research on to competition, but the course structure clearly deemphasizes this as a goal. The end product of most of this research is a formal paper and publication of an abstract in our high school *Journal of Science*, a booklet that serves not only as a source of pride but also as a reference for next year's apprentice scientists.

It takes more than motivation to generate problems for research from scientific literature. It takes experience and a structured approach to a problem, too. Persistence does pay off. The cost—less content covered—is far outweighed by the rewards. ■

Reference

1. Campbell, P. T., and J. C. Stanley. *Experimental and Quasiexperimental Design for Research*. Chicago: Rand McNally, 1966.

Do Mouthwashes Really Kill Bacteria?

by Thomas R. Corner

POOL
DISIN-
FECT-
ANT

Mouthwashes and disinfectants are good subjects for science fair projects. But students must be careful to judge effectiveness correctly.

As a science fair judge, I have seen many projects set up to test how well various household or other commercial products, such as detergents and mouthwashes, fight bacteria. Students have a hard time doing such research correctly. Generally, the young experimenters expose bacteria to filter paper discs treated with the product and then judge the effectiveness of the substance incorrectly by comparing the diameters of the zones of bacterial inhibition.

High school students seldom realize that a larger inhibition zone may not reflect a greater susceptibility of a test bacterium to a particular active ingredient; instead, it may reflect only a difference in the diffusion coefficients of the two active ingredients. The development of an inhibition zone is complex and depends upon a number of factors, many of which might be beyond secondary school scientists.

Two other errors, which are more serious, however, compromise the success of the project. The first involves the choice of broth media rather than solid media in Petri dishes; the second is the use of irregularly shaped bits of filter paper. The second error is considerably more common. Using broth defeats the whole idea of the test: to fix bacteria in space so that an inhibition zone can, in fact, develop. (The thermal agitation and bacterial motility, if any, in broth prevents zones from forming.) Irregularly shaped discs prompt irregular diffusion paths which are impossible to measure.

Nevertheless, the experiment is truly valuable. So let me suggest a better technique and, for advanced students, two additional procedures for introducing quantitative analysis into the experiment.

Impregnating filter paper discs with an antimicrobial agent is a reliable way to test the effectiveness of chemicals against various bacteria [8]. This technique forms the basis of standard antibiotic tests performed in most hospital and commercial diagnostic laboratories [4]. In these tests, pure cultures of the suspected pathogenic bacterium are exposed to discs of a single potency. Although different for each antibiotic, the concentration on the disc is carefully chosen, based on results from tests with different concentrations as well as on correlations with other types of analyses [4]. After incubation, a researcher measures the diameters of the inhibition zones and compares them to a standard chart, packaged with the discs, to determine whether the bacterium is fully resistant, fully susceptible, or of intermediate susceptibility. Only an antibiotic to which

MOU
LYSOX
G
BACTROX
KILL GERM
Johanna Vogelsang

the pathogen is fully susceptible would or should be used therapeutically.

How wide the inhibitions?

The diameter of the zone indicating full susceptibility varies markedly with both the bacterium and the antibiotic in question. Thus, an antibiotic to which a particular bacterium is resistant may produce a larger inhibition zone than another antibiotic to which the same organism is susceptible. (See Figure 1.) For example, a zone diameter of ≤17 mm indicates resistance to novobiocin in all bacteria tested, but a zone diameter of ≥11 mm indicates susceptibility to colistin in the same bacteria.

Similarly, for a given antibiotic, a large zone may or may not indicate susceptibility, depending on the bacterium being tested. For example, a zone diameter of ≥14 mm indicates susceptibility of *Escherichia coli*, but resistance of *Staphylococcus aureus* to ampicillin. In fact, for *S. aureus* to be considered susceptible to ampicillin, the zone diameter must reach at least 29 mm. Therefore, a student can neither compare the effectiveness of different agents against a single bacterium nor the degree of susceptibility of different organisms to the same agent simply by comparing the zone diameters without consulting reference tables.

I do not mean to say that you should discourage students, especially in lower grades, from doing the investigation. Rather, point out the problems and the necessary safety precautions, and encourage them to continue. They will gain not only useful bacteriological experience but also some insight into the merits of advertising claims.

At the outset of the experiment, students must decide which agents, organisms, growth media, and materials to use. In choosing antibacterial substances, students are limited only by their experience and imagination. Some examples include mouthwashes, household disinfectants, laundry detergents, toothpastes, and deodorants. Liquid products are easier to test but solids can be used in solution, such as 1 g dissolved in 100 mL of sterile distilled water in a sterile container.

Keeping it clean

Ideally, the products you want to test should be sterile. You can determine whether or not a product is sterile by pipetting several drops of it onto a plate of the growth medium you are planning to use in the experiment. Use a sterile pipette. Incubate the plate for at least one week at room temperature (or 3 days at 37° C). Products that show contamination (a lesson in itself) should be sterilized, preferably by passing them through a membrane-filter device (such as the No. 20 available from Nalge Co., 75 Panorama Creek Rd., Rochester, NY 14602). If the product contains alcohol (some mouthwashes and disinfectants) and

High school students seldom realize that a larger inhibition zone may not reflect a greater susceptibility of a test bacterium to a particular active ingredient.

must be sterilized, you *must* use a filter.

You can obtain pure cultures of nonpathogenic bacteria from most supply houses or from the American Type Culture Collection (12301 Parklawn Dr., Rockville, MD 20852; ask for Preceptrol cultures). *Escherichia coli* is probably the best choice because of its important role in the development of molecular biology and its ability to grow in simple media over a wide temperature range. But *Staphylococcus epidermidis, Bacillus megaterium, Bacillus subtilis,* and *Bacillus cereus* are easy to grow, too. A comparison between *E. coli,* a gram-negative bacterium, and one of the other three, all gram-positive bacteria, could make an interesting study. Bacteria of the genus *Streptococcus,* which constitute the bulk of the oral microflora [9], are the ideal choice for testing mouthwash. But they do not grow well on readily available media and present real safety problems; both of these facts argue against their use.

Breeding your own cultures

Alternatively, students can isolate and grow their own pure cultures. Household dust, garden soil, and unwashed fingers are good sources of bacteria. Students can harvest organisms from dust by inverting an open plate of growth medium over a dust source—under a bed or desk or in the corner of a room—and then tapping the plate gently on the dusty surface. This will blow organisms onto the agar. You will find it best to sample soil by preparing a slurry (for example, 1 g in about 100 mL of sterile distilled water). Allow the large debris to settle out, and then transfer a drop of the suspension to the plate of growth medium and streak the drop. You can sample finger bacteria simply by rubbing your fingers over the surface of the agar.

Whatever the source of the bacteria, incubate the plate at room temperature or other suitable temperature (such as 37° C until you can see colonies. If blood agar is available, isolate oral flora with throat swabs, but then use Mueller-Hinton agar for testing. (In collecting oral flora with throat swabs, you *always* face the possibility that you have pathogenic bacteria, even from healthy throats, in your sample. Therefore, swab only the surface of the tongue and teeth. Always caution students to use proper microbiological techniques at all times, and never let inexperienced students use pathogenic cultures.)

Once colonies of bacteria appear on the disc, use a sterile device, such as a bacteriological loop or needle, to transfer a single colony to fresh growth medium. Streak the colony so that after incubation you will have isolated colonies for a second time. One of these colonies can then serve as an inoculum to maintain slants (preferably in screw cap tubes). Prepare the slants by filling test tubes about half full with molten agar. Close the tubes and sterilize them. Then, while the agar is still hot, put the tubes at an angle of about 15°, and let the agar solidify. Each week, transfer the growth on the slants to fresh slants to maintain a source of inoculum for the test plates.

Media for growing

Any of the following growth media are suitable for the tests: nutrient agar (Difco Products, PO Box 1058, Detroit, MI 48232); tryptose blood agar base (no blood) (Difco); trypticase soy agar (BBL Microbiology Systems, PO Box 243, Cockeysville, MD 21030); and Mueller-Hinton agar (Difco and BBL). Most scientific supply houses carry these products. For the bacteria I mentioned earlier and for organisms isolated from natural sources, except throats and oral cavities, nutrient agar is adequate. The others are richer in nutrients. Standard antibiotic disc assay systems use the very rich Mueller-Hinton agar. You can buy all of these media in powdered form for reconstitution with distilled water followed by sterilization. Some media may be available (at higher cost) as prepoured plates and slants. You can also get newer instant media. Prepoured blood agar plates (tryptose blood agar base or trypticase soy agar plus 5 percent blood, usually from sheep) are sold commercially but sometimes may be obtained from a nearby hospital diagnostic laboratory. For organisms that are difficult to grow, you can add blood or serum to Mueller-Hinton agar.

The only other materials to which you should pay attention are the discs. Standard antibiotic assay discs are 6.4 mm in diameter and made of high quality paper. Blank discs are commercially available (for example, No. 31039 from BBL). However, students can use a standard notebook punch to make

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Figure 1. Zone diameters for interpretation of antibiotic disc susceptibility tests[a].

Antibiotic	Bacteria	Amount on disc (μg)	Zone diameters[b] for resistant (less than or equal to)	Zone diameters[b] for susceptible (more than or equal to)
Ampicillin	*Escherichia coli*	10	11	14
Ampicillin	*Staphylococcus aureus*	10	20	29
Colistin	all	10	8	11
Erythromycin	all	15	13	18
Novobiocin	all	30	17	22
Penicillin G	*Staphylococcus* spp.	10[c]	20	29
Penicillin G	all others	10[c]	11	22
Streptomycin	all	10	11	15
Sulfonamide[d]	all	300	12	17
Tetracycline	all	30	14	19

[a] Data adapted from [11].
[b] Zone diameters falling between the values given indicate intermediate susceptibility.
[c] This amount is given in units, not μg.
[d] Strictly speaking, sulfonamides are not antibiotics.

Figure 2. Primary active principles in selected brand-name household products.

Product [Reference]	Active Principle	Molecular Weight[a]	Molar Concentration (approx.)
Bleach			
Clorox liquid[b]	sodium hypochlorite	74.44	0.6717
Mouthwash			
Cepacol [1,3]	cetyl pyridinium chloride	357.99	0.0014
Chloraseptic [3]	phenol	94.11	0.1488
Fluorigard [3]	sodium fluoride	42.00	0.0119
S.T. 37 [1]	hexylresorcinol	194.26	0.0051
Soap or detergent			
Dial bar [6]	trichlorocarbanilide[c]	315.59	0.0002[d]
Diaperene [6]	methyl benzalkonium chloride	480.14	0.0012[d]
Dreft[b]	sodium dodecyl sulfate	288.38	0.0035[d]
Toothpaste			
Crest [1]	stannous fluoride	156.70	0.0026[d]
Macleans [1]	sodium monofluorophosphate[e]	143.95	0.0005[d]

[a] Obtained from [12].
[b] Data from product label.
[c] Hexachlorophene, listed as present [5], has been excluded.
[d] Concentrations based on a solution of 1 g in 100 mL.
[e] Sodium dodecyl sulfate is also present in this product [6].

Figure 3. Typical data for the action of household bleach (active ingredient: sodium hypochlorite) on *Staphylococcus aureus*.

Dilution[a]	Molar Concentration[b] (M)	ln M	Zone Diameter (mm)	Zone Radius (mm)	Corrected Radius[c] (r_c)	r_c^2
5/100	0.03	−3.51	7	3.5	0.3	0.09
1/10	0.07	−2.66	9	4.5	1.3	1.69
15/100	0.10	−2.30	10	5.0	1.8	3.24
1/4	0.17	−1.77	11	5.5	2.3	5.29

[a] Dilutions were made in sterile distilled water.
[b] Commercial liquid bleach is 5% sodium hypochlorite.
[c] Zone radius − disc radius = corrected radius; in this case, the disc radius was 3.2 mm.

their own discs from high-quality filter paper (such as Whatman No. 3). These discs, which will be about 7 mm in diameter, are perfectly suitable, but remember to sterilize them in an autoclave or pressure cooker.

Doing it

Inoculate the agar plates from the stock culture slants. Transfer a small amount of solid growth from the slant to the plate with a sterile bacteriological loop or similar tool. Spread out the inoculum evenly over the surface with a sterile swab. Moistening the swab with sterile distilled water makes the task easier. Be sure to cover the whole surface of the plate. The spread-out inoculum should not be visible.

Sterilize a pair of forceps by dipping them in ethanol. Allow the ethanol to drain off briefly. Then pass the forceps through a flame to ignite the residual ethanol. Be sure to keep the forceps pointed down. When the flame goes out, allow the forceps to cool for a few moments.

With the sterile forceps, pick up a sterile disc, and dip it into the product or solution you want to test. Allow the excess liquid to drain away, and then transfer the disc to the surface of the inoculated plate. One plate can conveniently hold four test discs arranged at 12, 3, 6, and 9 o'clock at 1 to 2 cm from the periphery. Push the disc down lightly with the forceps to make it adhere to the agar.

Repeat the procedure for each additional test disc. Place an untreated disc in the center of the plate as a control for filter paper toxicity. Set up one inoculated plate without a disc as a control for the growth of the organism.

Now incubate the plates at the same temperature at which you grew the stock culture of the test bacterium. (Be sure to carry out all comparative tests at the same temperature.)

When you begin to see bacterial growth on the control plate, usually after 24 to 48 hours, record the diame-

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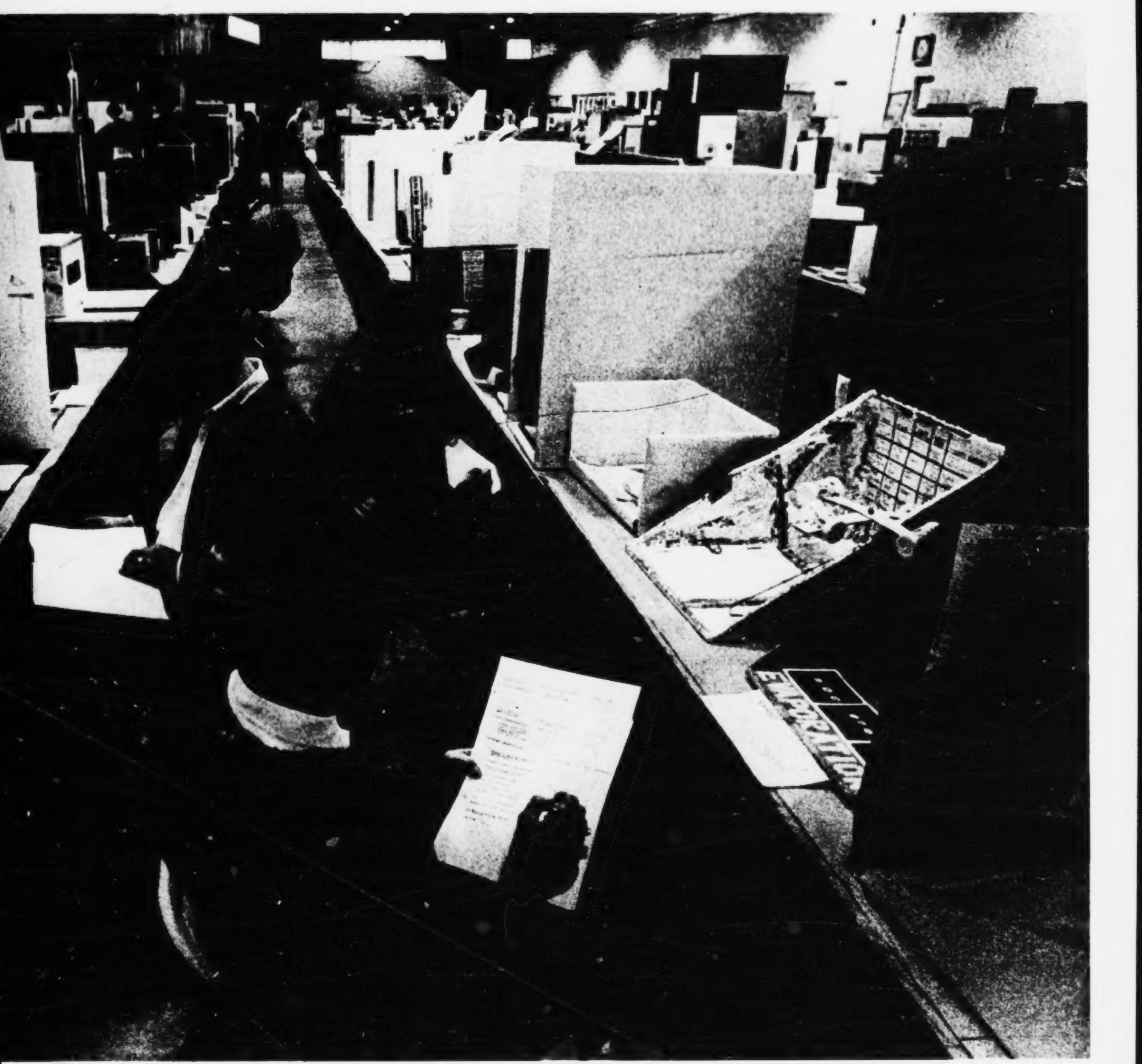

—Lynn T. Spence

disk drive, but it's not essential.

First you input the raw scores; then the program evaluates the average score for each project and performs a bubble sort to produce an ordered list of the project averages. This is where science fair scoring usually stops.

But our program goes on to compute a "correction factor" for each judge. We assign each of the judges *(n)* and each of the projects *(m)* a number, and we input a scoring array (SCORE) of dimension *n* by *m* to the computer. The variable SCORE*(I,J)*, for example, simply represents the score awarded to the *J*th project by the *I*th judge. If not all judges view all projects, many entries in the array SCORE will be blank.

You will always have at least some overlap among judges. The computer analyzes SCORE and determines the deviation of each judge's score from the average score of each project. From this you can establish whether the scoring of any individual judge is uniformly high, uniformly low, or totally inconsistent. Assuming it is not the latter, the computer assigns a multiplicative correction factor to each judge so that his or her scores more closely align with the average scores for the projects he or she evaluated.

The program then will correct the array SCORE and will reevaluate, rebubble-sort, and print out anew the

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—Thomas M. Staley, courtesy of Montgomery County, Md.

Meet Me at the Fair

by William G. Lamb and Peter Brown

> *Science fairs should be more like county fairs.*

During the mid to late 1960s, support for science fairs waned to the point where many sponsors just plain got out of the science fair business. Every teacher knows what science fairs are: research project competitions in which students present their results on three-sided exhibit boards a maximum of 75 cm deep, 120 cm wide, and 270 cm tall. Right? These science fairs follow the rules and regulations specified by the International Science and Engineering Fair (ISEF) as administered by Science Service in Washington, D.C.

Among other definitions for "fair," my old battered dictionary gives the closest one for both science fairs and county fairs: "a competitive exhibition (as of farm products)." I must admit that I was surprised by the emphasis in the definition because my idea of a county fair is as much rides and entertainment as pigs and pickles winning blue ribbons. In addition to these contests, county fairs have something else that traditional science fairs often lack: joy, sparkle, and diversity.

Last year in Oregon, a consortium of groups got together to start a state science fair after many years without ters of the inhibition zones. If your students have prepared duplicate (or more) plates, as they should have, they will gain some idea of the reproducibility and variability of such tests. Always remember to teach your students how to use safe techniques to prevent contamination. You may have to remind them about safety as they conduct the experiment.

Advanced students with a sufficient math background can use the filter paper disc assay to determine the minimum inhibitory concentration (MIC) of various products. MIC is the dose that is just sufficient to inhibit the growth of a given microorganism. Students can use the filter paper disc assay system to compare the effectiveness of various products against a particular bacterium [8].

But what about the moles?

To do the exercise properly, you must know the molar concentrations of the chemicals you are testing; therefore, carry out these assays only on pure solutions of an agent. You cannot apply this procedure strictly to most commercial products, of course, since they are mixed solutions of active and inactive ingredients. However, even with these products, your students will find the exercise instructive. Tell them to perform the calculations only for the major active principle. Figure 2 contains data for some typical household products. (In preparing this table, I found references 1 and 3 most helpful for product concentrations and reference 12 for molecular weights.)

The mathematical theory behind the relationship between the size of the zone of inhibition and the concentration of the product on the paper disc is not well developed because the test system cannot be analyzed in a straightforward way. For practical purposes, however, you will find the following approximation satisfactory [4, 8]. The relationship between the critical concentration (M') at which no zone will

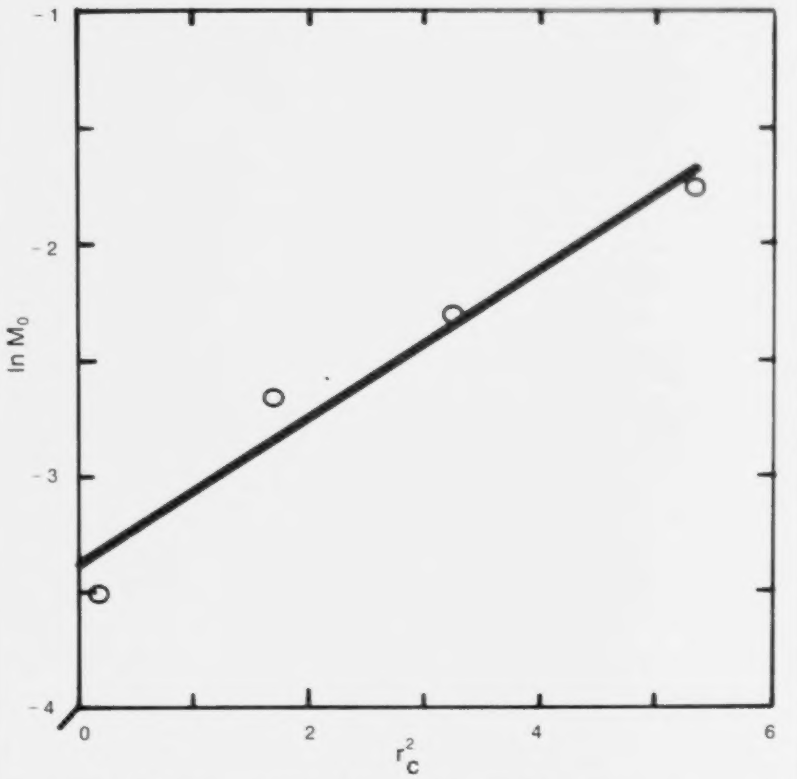


Figure 4. The effect of household bleach (sodium hypochlorite) on *Staphylococcus aureus*. The line shown was fit by least squares regression using a Texas Instruments TI59 programmable handheld calculator; but a visual "best-fit" could have been used. The y-intercept (ln M') is -3.39; therefore, the MIC (M') = 0.03M.

Figure 5. Hypothetical data for the comparison of two products for which the concentrations of the active principles are unknown.

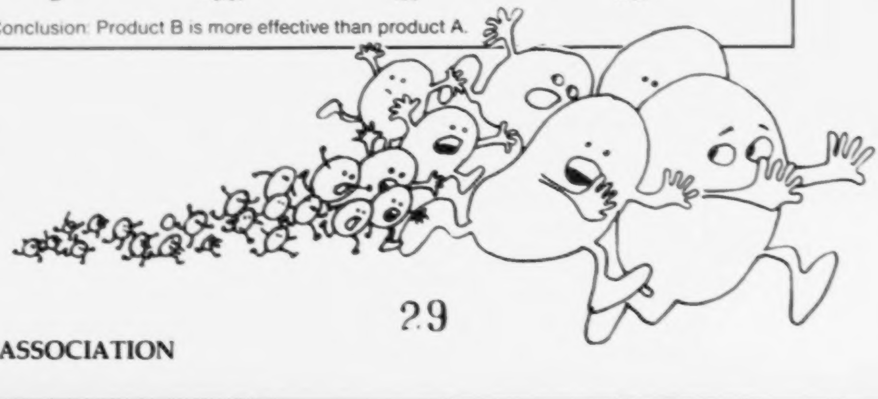
		Product			
		A		B	
Product Dilution	ln DDE[a]	Zone Diameter	r_c^2	Zone Diameter	r_c^2
undiluted	0.0	24	77.44	20	46.42
1/2	−0.69	21	53.29	18	33.64
1/4	−1.39	18	33.64	17	28.09
1/8	−2.08	13	10.89	15	18.49
1/16	−2.77	no zone	—	13	10.89

[a] Natural logarithm of the dilution decimal equivalent.

Summary

Product	ln (y-intercept)	$e^{\text{y-intercept}}$	Relative effective dilution
A	−2.43	.09	1/11
B	−3.57	.03	1/33

Conclusion: Product B is more effective than product A.



form around a disc, that is, the MIC, and the initial concentration (M_o) of the solution on the disc is given by the formula

$$\ln M' = \ln M_o - \frac{r_c^2}{4Dt}$$

where M' and M_o are the concentrations discussed above (in moles/liter), r_c is the distance from the edge of the disc to the outer edge of the inhibition zone around the disc (the corrected radius), D is the diffusion coefficient of the agent in the medium, and t is the time diffusion was allowed to occur.

Although the diffusion coefficients for various agents in nutrient agar are not readily available, you can determine M' under conditions in which you hold D and t constant. Simply use saturated discs on the same plate with different known concentrations (different M_o) of the agent. Determine M' by plotting the various M_o values against the square of the appropriate corrected radii. This is possible because when you rearrange the equation above, you will discover it is the equation of a straight line, $y = mx + b$, where m is the slope and b is the y-intercept. Thus,

$$\ln M_o = \frac{1}{(4Dt)} r_c^2 + \ln M'$$

This relationship is linear as long as D and t are held constant for each value of M_o. Although we are using this equation here to determine M' values for various products, you can also approximate D, the diffusion coefficient, if you keep accurate time records.

But will it really kill germs?

Now, test the undiluted agent against the chosen bacterium, and determine the diameter of the inhibition zone, if any. If there is no inhibition, try another agent or another bacterium. A large zone is better than a smaller one because you can dilute the product further before reaching a concentration that will not produce a zone.

Prepare twofold dilutions (that is, 1:2, 1:4, 1:8, and so on) of the product in sterile distilled water for as many tests as you want to run. Usually four dilutions will be sufficient; but if the zone for the undiluted product is large, you can test eight dilutions. Use the same methods you did in the first experiment.

Comparing the results

When inhibition zones develop, record their size in a table similar to the one shown in Figure 3, which shows experimental data obtained when *Staphylococcus aureus* was exposed to household bleach. Complete the required calculations to determine the critical inhibitory concentration of your agent for your organism by plotting the square of the *corrected radius* of the inhibition zone (total radius minus disc radius) versus the natural log of the concentration on the disc for each of the four cases. Extrapolate the line to the y-axis to obtain the natural log of the critical concentration. (Figure 4 illustrates the results of Figure 3, with an MIC of 0.03 M.) Ideally, for comparison, students should examine the action of two agents on a single bacterium or the action of a single agent on two different organisms.

You can draw a quantitative comparison of the effectiveness of two agents even when you do not have the appropriate concentration data (as is often the case with commercial products). You can also find the relative effective dilution, the theoretical dilution at which a zone just fails to form ($r_c = 0$), for each product. Carry out the tests exactly as described above, but substitute the decimal equivalents of the dilution factors, for example, ½ = 0.50, for the concentrations as illustrated for the hypothetical case in Figure 5. The resulting y-intercepts are the natural logs of the decimal equivalents of the relative effective dilutions. Taking the inverse of the antilogarithm of this number will yield the denominator of the dilution that should be made to produce $r_c = 0$. The smaller this number, the less effective the product, so a product with a relative effective dilution of 1:11, as in Figure 5, is less effective than one with a relative effective dilution of 1:33. Although this is not the ideal way to make comparisons of effectiveness, this method is quantitative, whereas simple measurement and comparison of zone diameters is incorrect and may be misleading.

These procedures for testing household and other products ought to help clear up your students' misconceptions about the relative effectiveness of these agents against various bacteria. Knowing the right way to obtain and interpret results accurately can be just the polish your students need to come up with some really sparkling independent research. ■

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Surviving a Science Project

by Martin D. Teachworth

A comprehensive project guide and a stringent schedule discipline these students to achieve their best.

While students elsewhere may do science projects, at Samuel Gompers Secondary School, our students do *science projects!* Gompers is a math/science/computer magnet school, so our students, while reflecting the cultural and racial mix of San Diego, arrive interested and sometimes talented in those subjects. We respond by teaching them the scientific method, by exposing them to professional scientists and scientific equipment, and by training them in the self-discipline and communication skills they will need to succeed. And we do it, to a great extent, through our science project program.

The science department requires a science project of all students enrolled in the 7th-grade science computer class and the 8th-grade physical/life science class, as well as in 10th-grade physics. The 10th graders may start their projects in the 10th grade and finish them in the 11th. We encourage 9th and 12th graders to do a science project, too, but it's not required.

After teaching hundreds of students how to start and complete projects, I think I have learned something about how to help students succeed at them. Students of all abilities have some problems in common: How to set up equipment and procedures, conduct an investigation, and report findings is a big one.

Many students, especially 7th and 8th graders, have poor writing skills and undeveloped scientific thinking skills. These students need the most help. At Gompers, their teachers use lectures and handouts to supplement the standard format for science projects that the science department has agreed on (see Figure 1). Our standard format for the students' written report includes the components of a college-level report.

Time for quality

Once students learn how to set up projects and to communicate findings, their projects get better, especially at the 7th-grade level. When students understand the mechanics of a science project, they have time to be more creative, and the result is higher quality projects.

Another major problem is scheduling work time, and at Gompers we address it very aggressively. Students are to work on their projects at home or after school, not during class time. In class, teachers explain how to do particular aspects of projects, as well as cover the normal topics using laboratories, lectures, and demonstrations.

Students are human, and it is human to procrastinate—but our detailed schedule really helps. At the start of each school year, each student receives the schedule; the parents also receive a copy of the schedule and an explanatory letter. The letter explains the

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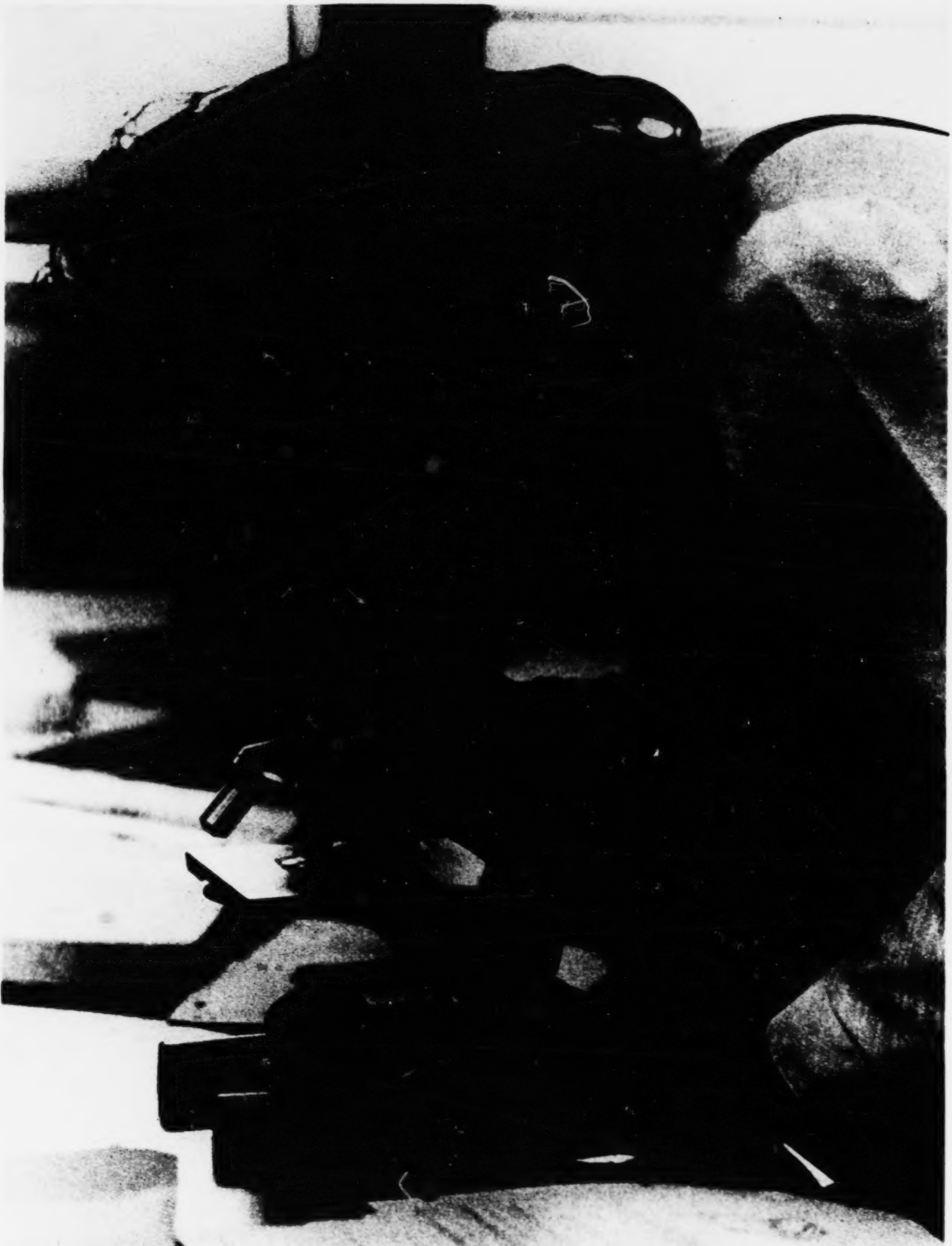


importance of the project and the need for their child to meet the scheduled due dates. It also asks them to check daily on their child's progress.

If the student misses a due date, we inform the parents with another letter home that also lists the next assignment and due date. If the letter isn't signed and returned, we contact the parents by phone. At first this process may take a lot of time. But as the semester progresses, students realize that working at meeting their due dates is better than having their parents contacted over and over.

Figure 1. Our science project guide.

The steps in the science project are listed below in the order of appearance. Use this sheet as a checklist when completing the parts of your science project.

1. Identification page: Give project title, your name, your advisor's name.
2. Title page: Give project title; no names.
3. Table of contents: List in order each project part (abstract to time log). Give page numbers for each project part.
4. Abstract: State the problem/question. State the hypothesis. Summarize the procedure. Summarize the conclusion.
5. Introduction: State the problem/question. State the hypothesis.
6. Variables: Identify the experimental variables. Explain how you will change the experimental variables in each group tested. Identify the controlled variables. Explain how you will keep each controlled variable constant in all groups tested.
7. Review of literature (research): Restate the problem/question as a topic paragraph. Introduce how or why you selected the project. Summarize what you learned about the topic, question, and hypothesis of the project. (This should be the body of the paper.) State what you think will occur during the experiment and why, according to your research. A minimum of 9 references is required—3 books, 3 magazines, 2 encyclopedias, 1 personal contact. (See your advisor for help.)
8. Equipment: List in detail all the equipment and materials used in the experiment. Exactly describe the equipment and materials and quantities of materials you used.
9. Procedure: Number and list each step in the order performed during the experiment. Detail only one specific action in each step. (Any person should be able to read the procedure and exactly repeat your experiment.)
10. Results: Give raw data (data recorded during experiment), smooth data (data placed in labeled charts or tables), and analyzed data (data interpreted in graphs, charts, and tables).
11. Conclusion: Restate the problem/question as a topic paragraph. State in a paragraph the conclusion reached about the problem/question. (If there is more than one problem/question, then write one paragraph for each.) Refer to the analyzed data to explain how you reached each conclusion. (Each major point gets its own paragraph.) Refer to the research to support your data and your conclusions when you refer to the analyzed data. In a paragraph, summarize all your conclusions and the major points you used to make the conclusions.
12. Suggested improvements: Explain how your project can be improved or expanded beyond what was tested.
13. Application: In a topic paragraph, restate your conclusion about the problem/question. List a possible application your conclusion or finding could have to real problems or situations. Refer to problems or previously unknown areas of knowledge you discovered while conducting the literature and experimental research.
14. Footnote page: Follow a standard footnote format to cite any footnotes to the research or conclusion section of the project.
15. Bibliography: Follow a standard bibliography format to cite all references used.
16. Acknowledgments: Follow a standard format to cite all the people who helped you with the project.
17. Time log/journal/record book: In a separate binder or folder, list all times, dates, activities, and work conducted during the project. (Sample entries include library work, developing your problem/question, locating and obtaining materials, constructing equipment or data charts, recording data, observations you made during testing, writing, and so on.)

"The whole is greater than the sum of its parts."

Scheduling due dates helps students pace themselves. They know exactly how much time is allotted for each part of the project, and at each step their teacher examines the project and makes suggestions. This immediate feedback improves project quality as, from year to year and project to project, students learn how to design and carry out projects—to think like scientists.

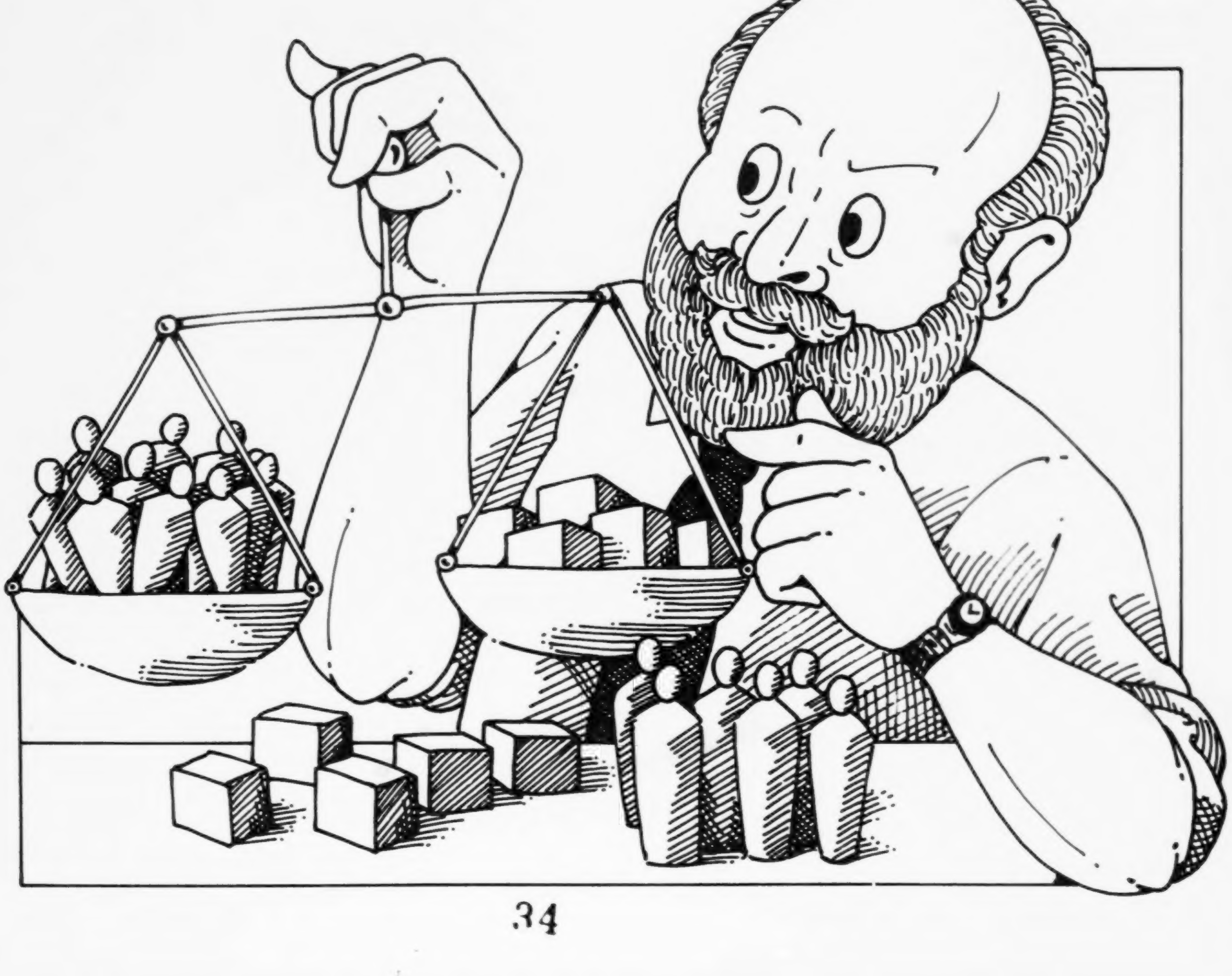
Students learn how to design and carry out projects—to think like scientists.

When the project is finally completed, students get a tremendous feeling of relief that an assignment that took 5 months is over. And they feel satisfied with completing a major assignment, often their first. While in a sense the projects are cooperative efforts among students, teachers, and parents, it is the students who learn how to start and complete an apparently overwhelming assignment.

Many of our students enter and win awards at the school's science fair. Many have their projects selected by the Greater San Diego Science and Engineering Fair for competition against students from San Diego and Imperial Counties. Our students do well in competition, and some have gone on to state and international science fairs. Their winning is proof that the great emphasis we place on science projects is an investment that pays dividends. ■

Fair Evaluation

Science fairs should be valuable for everyone. If yours is not, why not reevaluate it? Do the projects exhibit the goals of science teaching? Do the judges use consistent and objective criteria? Are all students "winners?" Science fairs should not just be a timeworn tradition. They can be fun and challenging for all. Don't be afraid to evaluate or change the way you prepare for and judge your science fair.



Does Your Science Fair Do What It Should?

by Eugene L. Chiappetta and Barbara K. Foots

It's time to reevaluate our approach to these familiar research competitions.

Every year thousands of students—bored, scared-to-death, excited, and confident—assemble their displays at science fairs across the nation. But why? Do they look forward to science fairs? Do our department chairpersons and district coordinators? Do we?

Science fairs can disappoint many students. After all, very few win prizes at the competitions. We ourselves often become frustrated when fairs demand too much energy and take away time we'd rather spend in front of our classrooms. Administrators feel overburdened when they have to organize facilities and solicit judges. But science fairs should be valuable for everyone. If yours is not, why not reevaluate it?

To be a success, a science fair must encourage students to ask the right questions—the whys and the hows. The following tips might be helpful:

- Encourage students to conduct science investigations that demonstrate the ability to ask the right questions and to find answers.
- Give students opportunities to collect data over an extended period of time and to analyze the data to determine the effect (or lack of effect) of a variable or procedure.
- Help students sharpen their inquiry skills beyond what is possible during classtime.

Many projects entered in science fairs do not emphasize investigation. Science fairs are often an incredible potpourri of

- models (volcanoes, animal organs, planetary systems, atoms) reproduced from pictures in printed materials
- hobbies or pet show-and-tells (horses, cars, leaves, arrowheads) that present information already available
- laboratory demonstrations (distillation, electrolysis, erosion, human pulse rates) that students have copied from a manual
- report-and-posters based on a review of books and magazine articles (birds, cats, trees, fossils, the universe)

Breeding Ben
Insects for the
Organic Gard

- investigative projects that depend on critical thinking and science process skills ("What materials offer the best insulation?" "What characteristics of an airfoil generate the greatest amount of lift?" "What factors are necessary for a seed to germinate?").

Anti-emperialism

All of the projects listed above emphasize investigation, but to wildly varying degrees. So how objectively and fairly can someone evaluate them? It's the old "apples and oranges" dilemma. You cannot apply the same set of criteria to such different projects.

Furthermore, we do the model builders a disservice if we don't encourage them to go further than to reproduce a concept or an idea. Why not suggest that students include models as one aspect of an investigative project? For example, after a review of the literature to determine the differences between normal and cancerous cells in various tissues, a student might build a series of models of both types of cells.

This example, you might object, is not really an investigation because the student has not collected and analyzed empirical data. Not all investigations, however, are empirical. Some of the most noted scientists based their theories on the research findings of others—Einstein was one. Recently, for example, we judged an outstanding middle school fair project on steroids. The project was an in-depth study on numerous aspects of steroids, including their use in athletics and cancer treatment. Although there was no empirical data, it was a great project.

Science fair projects should be an integral part of course requirements because they reinforce what students learn in a good science program. Because fairs build inquiry skills, students are soon asking researchable questions, gathering information, and drawing their own conclusions. Science projects promote independent learning, encouraging students to pursue their own interests.

The five criteria

The criteria we use to judge science fairs need to address inquiry as well as individual effort. The first criterion is creativity. Focus on the uniqueness of the project. How worthwhile is the project, given the age, background, and ability of the student? Interview the student to find out whether he or she designed the project based on a personal interest or whether the project was suggested by a parent, teacher, or another adult. To what extent is the project an out-

ial
HOW FUNGUS CAN SOLVE THE WORLD FOOD PROBLEM
How Men are Anatomically Superior to Women
PHYSIOLOGY OF How Women Are Superior to Men

—Marilyn Kaufman

Science fairs reinforce what students learn in a good science program. Because fairs build inquiry skills, students are soon asking researchable questions, gathering information, and drawing their own conclusions.

growth of the student's science course?

How much scientific thought did the student put into the project? Judges must determine the extent to which a student has taken in hand the investigative tools of science: observation, classification, inference, measurement, project design (control and variable), and others. Does the procedure fit the problem? A project on the effects of interferon cancer treatment would demand extensive research and careful organization. In contrast, a project on the effects of temperature on seed germination would require a carefully controlled experiment and the collection of accurate data over an extended period of time.

How well does the student understand the project? She or he should have read about the topic and be able to discuss data, concepts, and theories. The project should exemplify how a scientist conducts a research study. Students must be able to point out where in their investigations ideas are tentative and, in this way, realize the limitations of the data that they have gathered. Students must learn to avoid using the term *prove*. Science supports or refutes ideas, but it does not try to prove anything.

Consider the craft of a project. Students spend a great deal of time and effort in presenting what they have done. Give them credit for how well they display their work—neatness, organization, and visual appeal. Since youngsters often get help from their parents and other adults, try to determine how much others contributed so that you can reward a student for his or her own effort.

Finally, how well can students explain their investigation? Can they clearly communicate the problem, procedures, information gathered, and the conclusion both orally and in written form? How clearly does the project present the data and results?

The maximum number of points awarded in each of these five categories should reflect the purpose of a science fair. Generally, assess more points in the categories of creativity, scientific thought, and understanding than in workmanship and clarity. Be sure that judges and students know the criteria and the point system in advance.

Even with the best criteria, other problems can crop up. Be ready. Competition can sometimes detract from the goals of science fairs. Often parents get too involved because they want their children to win. By giving too much guidance and direction, they rob students of opportunities to develop their own creative abilities and to learn self-motivation. This also places students who do most of their own work at a disadvantage. Some school districts have even discontinued science fairs because parents were overinvolved in their children's science fair projects.

Plan it right

At times, school district fairs also put undue pressure on science teachers. Frequently, we must devote too much class time to these events. We often feel burdened with excessive paperwork and laboratory preparation in addition to our regular course instruction. Sometimes it seems that science fairs just add to the workload. The key to avoiding such problems is, of course, planning. A science fair committee of teachers and parents should establish a timetable and judging criteria, handle publicity, select awards, and explain what students are expected to do.

Establish early in the school year the purpose for the fair in your school and district so that students and teachers realize that projects should reflect the investigative aspect of science as well as the influence of science and technology in society. Arrange for students to work on projects throughout the school year so that the science fair will be a natural extension of your science course and the district's science program.

Science fairs should not be just a time-worn tradition. They can be fun and challenging for both students and teachers. But we must not be afraid to overhaul them, to make some real changes in the way we prepare for them and the way we judge them. These crazy-quilt displays of varied talent and effort should be a highlight of the academic year. ■

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INJECTING OBJECTIVITY INTO SCIENCE FAIR JUDGING

Use of a standard evaluation form reflecting specific criteria may help to clarify science fair goals for both students and judges.

Harvey Goodman

Many science fair evaluators have suffered at one time or another from the nagging feeling that judging is, at best, subjective and, at worst, borders on the arbitrary—a sad commentary in light of the tremendous amount of effort that students put into their projects.

A major part of the problem undoubtedly lies in the fact that we have not well defined the goals of science fairs, nor evaluated how these coincide with the broader goals of science teaching. In a recent article in *TST*, for example, author Norman F. Smith pointed out how few projects are investigative, involving students in critical thinking and science processes.[1] Most awards, he observes, still go to traditional "library research and poster" projects.

Another factor that may account for the subjectivity of the judging process is the lack of availability of objective criteria—criteria so designed that a judge evaluating a project in a specialty other than his own could arrive at a conclusion that is at least comparable with that of other members of the judging team.

Traditionally, judges are asked to evaluate students' projects according to a scheme that looks something like the following:

Creativity (30 points)
Logical Thought (25 points)
Thoroughness (10 points)
Skill (15 points)
Clarity of Presentation (15 points)

What is the likelihood that two judges using this scheme could arrive even approximately at the same point value for a project? How helpful are these criteria to a student planning a project? How is creativity to be evaluated?

Usually, when one evaluates a project, one has (or should have) some criteria of a different sort in mind. What one really is looking to see is, for example: whether the project really reflects the problem statement; whether the hypothesis arose from adequate background reading; whether the procedures used were appropriate for the problem; whether the observations were accurately recorded and appropriately displayed; whether the apparatus was appropriate for the experiment; and whether further research problems were suggested by the project.

How can one get judges to focus on these criteria (or whatever standards are decided on)? I would suggest that we begin by drawing up standard evaluation forms which reflect the values of each fair and which direct the evaluator's attention to specific elements of the project. The format might look something like the following:

Science Fair Project Evaluation Form

0 = Cannot make a judgment
1 = Poor
2 = Fair
3 = Satisfactory
4 = Good
5 = Excellent

Rank each of the following based on the rating system given above:

The problem was clearly stated. *(Problem formulation.)*
Appreciable time was evidently spent searching for and reading scientific articles. *(Background reading.)*
Background reading was appropriate both in quality and scope. *(Background reading.)*
The hypothesis was stated clearly and reflected the background readings. *(Hypothesis formation.)*
The experimental design demonstrated understanding of the scientific method. *(Methodology.)*
Apparatus and equipment were appropriately designed and/or used. *(Materials.)*
Observations were clearly summarized. *(Observations.)*
Interpretation of data conformed with observations. *(Observation.)*
Tables, graphs, and illustrations were used effectively in interpreting data. *(Observation.)*
Conclusions and summary remarks were justified on the basis of experimental data. *(Conclusion.)*
The experiment was repeated several times to establish validity of results. *(Validity.)*
A log book was used to record experimental data, ideas, interpretations, and conclusions. *(Record keeping.)*
The bibliography contained a significant number of relevant and timely references. *(Background reading.)*
Limits of accuracy of measurements were stated. *(Measurement.)*
Work on the project suggested new problems for future research. *(Future research.)*
Oral presentation was made in the time allotted, with all phases of the project discussed. *(Interview.)*
The researcher answered questions effectively and accurately. *(Interview.)*
The oral presentation made good use of visual aids. *(Interview.)*
The student initiated his or her own research project. *(Initiative.)*
The display board was effective in presenting the project. *(Display board.)*
The maximum number of points that a candidate may obtain is 100 percent; awards may be granted in accordance with the following scores:
60 - 69—Honorable Mention
70 - 79—Third Prize
80 - 89—Second Prize
90 - 100—First Prize
In the event that a judging team consists of two or more members, the final score is the team average.

. . .

If the goals of each science fair were adequately described to judges, if judges were given evaluation forms reflecting specific criteria by which projects could be evaluated in a more objective way, we would all benefit—students, teachers, and judges. ■

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[1] "Why Science Fairs Don't Exhibit the Goals of Science Teaching," by Norman F. Smith, *The Science Teacher* 47:22; January 1980.

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JUDGE'S GRADES
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JUDGE

IN THE

Lawrence J. Bellipanni
Donald R. Cotten
Jan Marion Kirkwood

You have just hung up the telephone after a brief conversation with the science teacher at a local junior high school, and somewhere along the line you've "volunteered" to be a judge for the school's science fair. Suddenly you are responsible for evaluating projects that students may have spent months working on and for deciding which projects are best. Making these decisions is no easy task, but if you keep a few points in mind, you can turn your judging duties into a rewarding experience for both you and the students.

Regardless of the grade level you're working with, you should note the quality of the work the students have done and determine how well they understand their projects. The project should include research, experimentation, and application—not simply library work. But as you apply these standards, always consider the grade level of the student whose project you're judging and the general level of expectation for that particular fair.

Here are some specific criteria to use:

1. *Creative ability.* Has the student shown intelligence and imagination both in asking the question and arriving at the answer? Is the student original in deriving and applying data? Did he or she build or invent any equipment to use in the project?

Remember, anyone can spend some money, but it takes a creative person to devise the equipment needed for a particular project. Ask students where they got their ideas. Creative students are always coming up with new twists to old ideas; such ingenuity indicates that you're dealing with an interested young scientist. Collections may show diligence, but they seldom show creativity. So don't be tempted into giving them high marks unless they have some true scientific merit.

2. *Scientific thought.* Is the problem stated clearly and unambiguously? Did the student think through the problem and pursue his or her original question

Suddenly you are responsible for evaluating projects that students have spent months working on and for deciding which ones are best.

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BALANCE

without wandering? Was the experimental procedure well defined and did the student follow each step toward the expected outcome?

Did the student arrive at the data experimentally (as opposed to copying them out of a book)? Are the data relevant to the stated problem? Is the solution offered workable?

3. *Thoroughness.* A solid conclusion is based on many experiments, not a single one. Does the project test the main idea of the hypothesis? How complete are the data? How well did the student think through each step of the experiment? How much time did he or she spend on the project? There are few loopholes in a project that has been done thoroughly. Ask the student questions about the project to determine how well he or she understands the problem.

4. *Skill.* Since you don't know the students personally, you will need to have some way of determining how likely it is that they did the work themselves. Ask them if they had any help with their projects. (But use common sense here. If the project requires using an electric saw and the student is in third grade, it would be permissible—indeed advisable—for an adult to perform this task.) You can usually tell how much of the actual work students have done by observing them while they demonstrate or explain the project.

5. *Clarity.* The project should be set up so that the judge can follow the procedure and understand the data without getting confused. Students should have written the data clearly, using their own words, and they should be able to discuss any portion of the project. The main purpose of the project is to show that students can formulate, test, and present research.

Though these five criteria are basic, the standards for judging particular science fairs may vary, depending on the grade level of the participants or the types of projects involved. The teacher supervising the science fair should make certain that each judge has a judging sheet, indicating not only the criteria to be used but the points that each item is worth. If you do not understand one of the criteria, ask the teacher or coordinating judge for clarification before judging begins. Your responsibility to the children is to be as fair and objective as possible, and that can happen only if all the judges use the same criteria in the same way. And remember: each child's project is very important to that student. So whether the project merits a blue ribbon or not, be sure to provide proper encouragement so that students will continue to investigate their own ideas.

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WHERE DOES
EFFECT OF CAUSTIC ON VARIOUS METALS

Make Your Science Fair Fairer

by B. J. Lagueux and Howard I. Amols

> *Mr. Weiss can't bear to give a score lower than 90; Mrs. Estevez hasn't liked anything since 1978. How can you help the best project win first prize?*

Does the idea of choosing the winners at your science fair make you nervous? Do you constantly worry about being fair to all the participants? Do you secretly wonder if you and your fellow judges are biased, and do you despair that because of judging discrepancies the best projects will not win?

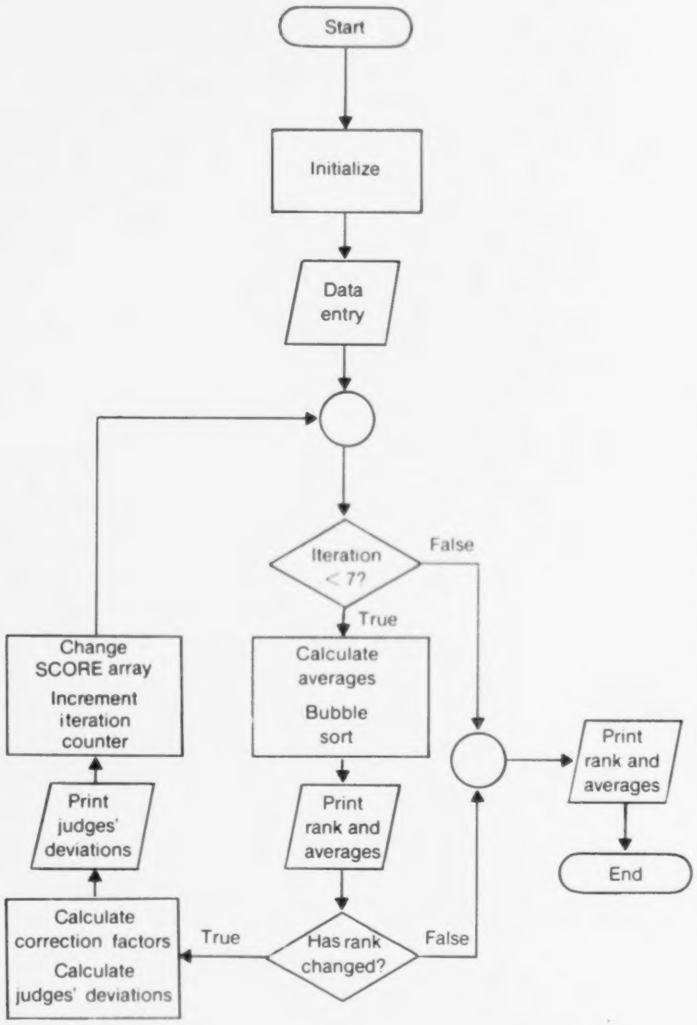
Fear no more! Eliminate the ambiguity from those subjective evaluations with a computer program for judging science fairs. No matter how quantitative science fair projects might be, the way we determine the best projects must be subjective. In a small science fair, where each judge can evaluate all projects entered, we hope the subjectivity of the judges will "average out." If your science fair has few judges, the judges can often arbitrate discrepancies in scoring.

But in a large science fair, how can every judge evaluate every entry? As your science fair grows, so does the probability that the winning projects will be determined as much by judging inconsistencies as by merit.

We have developed a small computer program, written in BASIC to run on any personal computer, that you can use as an aid in scoring. The program evaluates not only the scores awarded to each project but also the relative scoring level of each judge. It can identify judges who routinely give projects very high or very low scores and can correct for those scores before it determines the average score of any individual project. Judges who are excessively inconsistent can also be identified and their scores corrected or even eliminated before you decide the winners.

Our program was written for use with Microsoft DOS, on an IBM-PC, but it is easily adaptable to any personal computer with at least 20K memory. It would help to have a printer and a

Figure 1



Art by Dick Steele

average project scores. The second printout gives you a winners list that has been corrected for variation among judges. You can repeat this procedure in a DO-LOOP until the project rankings from one iteration to the next do not change. Then you can reasonably conclude that judging inconsistencies have been eliminated, or at least reduced as much as possible.

The program ends after a maximum of six iterations or when the ranking converges—when the ranking is identical to the ranking from the previous iteration. Occasionally the ranking fails to converge because of the repeated interchanging of adjacently ranked projects, projects that in reality are tied.

Ending the DO-LOOP

We have found that no more than six iterations are required to correct for the variation among judges; ending the DO-LOOP at that point significantly decreases the program's running time. The ranking of projects that have been judged by consistent judges, however, will often converge after only two or three iterations.

Figure 1 is a flowchart that represents about 200 lines of actual coding of the program. Write to us if you want copies of the program itself.

We tested the computer program with data from four hypothetical cases. To do this, we had to work backwards—we had to establish a "true" score for each project and then to create judges who scored the projects too high or too low compared with the true scores. When you use our program, of course, you will work not from "true" scores but from the raw scores of your judges. In all our tests, SCORE was a 5 by 10 array, corresponding to 5 judges and 10 projects. Each project was scored by two different judges; each judge scored four different projects; so the 5 by 10 array contained 20 unique scores.

In the first two test cases (see Figures 2 and 3) we assigned all projects a "true" score of between 85 and 60. Our hypothetical judges always score the projects proportionately to the projects' true scores. Then we assigned each of the five judges an arbitrary weighting factor of between 0.65 and 1.15, to represent judges that score consistently low and consistently high, respectively. A weighting factor of 1.00 indicates a judge who scores projects perfectly. We chose which judge scored which particular project by using a table of random numbers. (Figures 2 and 3 differ only in that the judges scored different projects; the same is true of Figures 4 and 5.) The program produced the array by multiplying a judge's weighting factor by a project's true score.

As you can see in Figures 2 and 3, the program reordered the projects in accordance with their true scores. The tables give each project's true score, true rank, judged scores, initial rank (based on a simple average of the judged scores), and iteration ranks. Note that some projects should have tied because they had equal true scores.

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Figure 2. Program output for Test Case 1, with theoretically perfect judges.

Project	True score	True rank	Judge (correction factor)					Initial rank	Rank after iteration					
			A (0.65)	B (0.75)	C (1.00)	D (1.10)	E (1.15)		1	2	3	4	5	6
A	85	1	55	—	—	94	—	3	1	1	1	1	1	1
B	80	2-3	52	60	—	—	—	9	2	3	2	3	2	3
C	80	2-3	—	60	—	—	92	1	4	2	3	2	3	2
D	75	4	49	—	—	—	86	6	7	4	4	4	4	4
E	70	5-7	—	—	70	77	—	4	3	5	5	5	6	6
F	70	5-7	—	—	70	—	81	2	5	6	6	7	5	7
G	70	5-7	—	53	—	—	81	7	9	7	7	6	7	5
H	65	8	—	—	65	72	—	5	6	8	8	8	8	8
I	62	9	40	47	—	—	—	10	10	10	9	10	9	9
J	60	10	—	—	60	60	—	8	8	9	10	9	10	10

Figure 3. Program output for Test Case 2, with theoretically perfect judges.

Project	True score	True rank	Judge (correction factor)					Initial rank	Rank after iteration		
			A (0.65)	B (0.75)	C (1.00)	D (1.10)	E (1.15)		1	2	3
A	85	1	—	—	—	94	98	1	1	1	1
B	80	2-3	—	—	80	—	92	3	3	3	3
C	80	2-3	—	—	—	88	92	2	2	2	2
D	75	4	—	—	75	83	—	4	4	4	4
E	70	5-7	46	53	—	—	—	8	7	6	6
F	70	5-7	46	53	—	—	—	9	8	7	7
G	70	5-7	—	—	70	77	—	5	5	5	5
H	65	8	42	—	65	—	—	7	6	8	8
I	62	9	—	47	—	—	71	6	9	9	9
J	60	10	39	45	—	—	—	10	10	10	10

Figure 4. Program output for Test Case 3, with judging variations of ±5 and ±10 percent.

Project	True score	True rank	Judge (correction factor)					Initial rank	Rank after iteration				
			A (0.60-0.69)	B (0.65-0.83)	C (1.00)	D (1.00-1.18)	E (1.10-1.19)		1	2	3	4	5
A	85	1	—	—	85	94	—	1	1	1	1	1	1
B	80	2-3	49	—	80	—	—	5	3	2	3	3	3
C	80	2-3	48	66	—	—	—	9	2	3	2	2	2
D	75	4	50	52	—	—	—	10	5	5	4	4	4
E	70	5-7	43	—	—	—	83	6	6	6	6	5	5
F	70	5-7	—	50	—	—	79	4	8	7	7	7	7
G	70	5-7	—	—	70	78	—	2	4	4	5	6	6
H	65	8	—	47	—	—	73	8	10	8	8	8	8
I	62	9	—	—	62	62	—	7	7	9	9	9	9
J	60	10	—	—	—	65	63	3	9	10	10	10	10

In the most dramatic example of the effect of our program, Project B in Figure 2 was originally ranked ninth of 10 projects because it was judged by two low-scoring judges. The program identified these judges, weighted their scores, and reranked this project to second or third place, depending on the iteration.

The third and fourth test cases were identical to the first two, with the exception that we chose to randomly vary four of the judges' weighting factors by up to either ±5 or ±10 percent. (See Figures 4 and 5.) In these tests, the judges were not perfectly consistent.

For these two cases, the program was able to rerank one set (Figure 4) to correspond with the projects' true scores. The program improved the second data set (Figure 5), but the judges' scores were too inconsistent for the program to rank all projects perfectly. Figure 5 represents a particularly skewed set of scores. For example, Judge B gave Project B a disproportionately low score of 54, while giving two weaker projects (D and E) higher scores (56 and 57, respectively).

Rank failure

The program's failure to effectively rank the data in Figure 5 illustrates one of the limitations of the program's scoring analysis. The algorithm of our method assumes that each judge's scoring is proportional to each project's true score. In reality, judges' scores will vary around a proportionality factor, as in Figure 5. The program compares each judge with fellow judges, to find the best proportionality factor, and corrects scores accordingly. The program cannot, however, reliably correct for a judge's variation around his or her own proportionality factor.

In the data from Figure 5, the judges' variation around their respective proportionality factors was too great given the number of judges and the number of judges scoring each project. The program's scoring method compares a judge's score with other judges scoring the same project, as well as with the project's average score. The only way to reduce the importance of a judge's variation is to increase the number of "judge-scorings." This could be done by either increasing the number of judges, increasing the number of projects that each judge scores, or both.

Given the small number of judge-scorings in our four test cases, the program was not always sensitive enough to retain the equal standing of truly equal projects. Projects B and C had the same true score of 80, and Projects E, F, and G had the same true score of 70. In our first test case (Figure 2), these rankings did not converge, and so indicated equal standing. In the other three test cases our program was unable to indicate the equal standing of equal projects.

We then tested the program using data from an actual science fair. In this real case, the winners would have been different if our program had been used. One of the projects that tied for first place would have ranked seventh, and the fourth-place finisher would have ranked second. The third-place project would have remained in third place.

This change in outcome indicates that there was some systematic variation among the judges. This is not surprising when you consider the varied backgrounds and specialties of the judges. Among the 36 judges in the fair were high school teachers, college professors, physicians, nurses, and engineers.

To ensure adequate overlap among judges and an accurate average score for each project, you must be sure to recruit enough judges so that at least three judges review each project. Also, in order for the computer to calculate an accurate proportionality factor for each judge, have each judge review at least four projects. Typically, a judge spends between 15 and 25 minutes judging a project. A judging session of 2½ hours will allow enough time for each judge to review between six and eight projects.

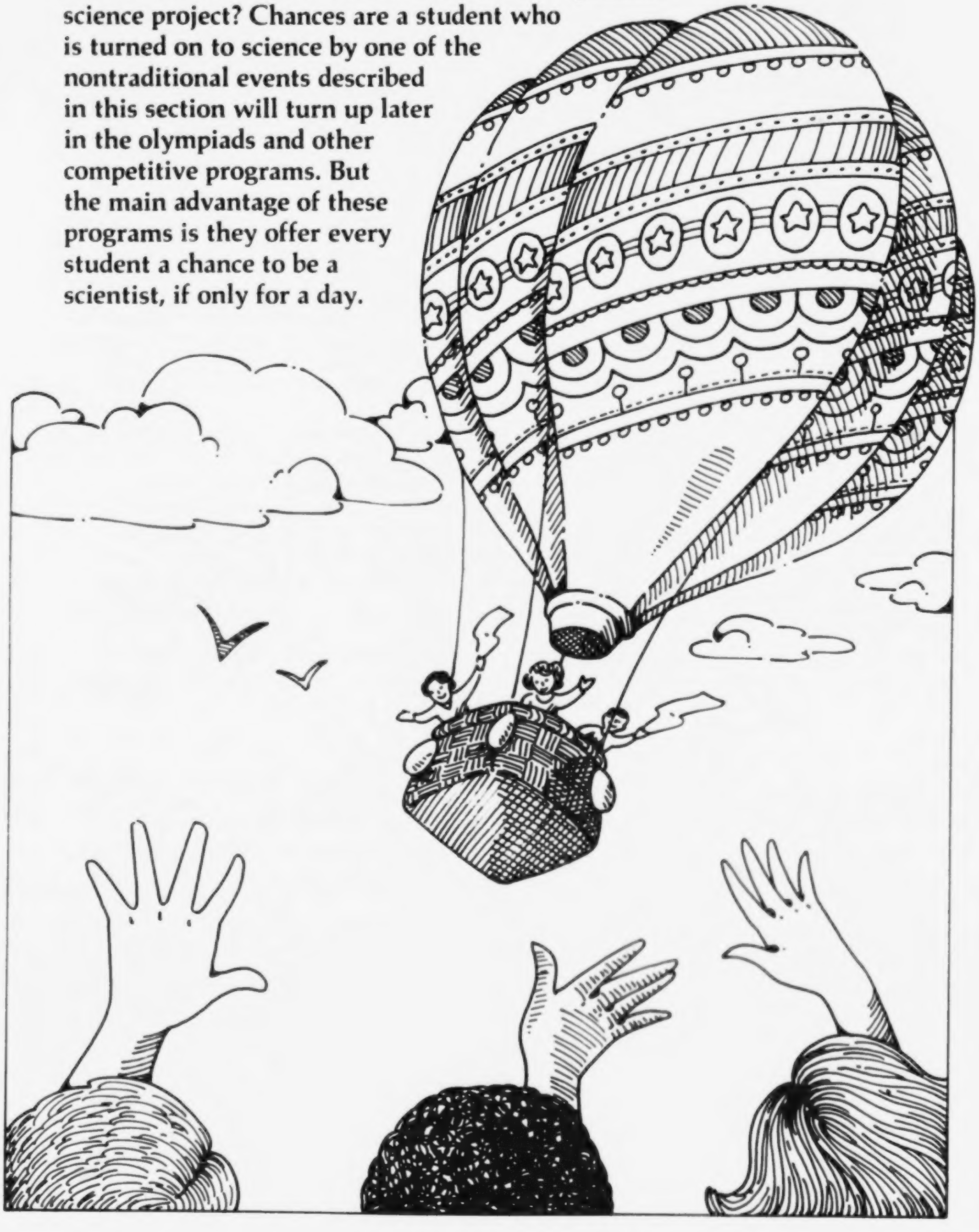
What about the excessively slow judge who will never review six projects in one evening? That judge could keep the whole fair waiting. Simply randomly assign judges to projects. Have judges first report to the organizer's table to receive a score sheet. Then they can judge a given project at their own pace and return to the organizer's table for the next project assignment. Because each judge has a correction factor calculated in our program, having judges score a different number of projects will not bias the results.

You can use this program to reevaluate your science fair judging, to help ensure that winning projects are selected fairly. At the very least, the program can help you identify cases of inconsistent judging, so you can alert the fair's organizers to potential problems. ■

Figure 5. Program output for Test Case 4, with judging variations of ±5 and ±10 percent.

			Judge (correction factor)						Rank after iteration					
Project	True score	True rank	A (0.60-0.69)	B (0.65-0.83)	C (1.00)	D (1.00-1.18)	E (1.10-1.19)	Initial rank	1	2	3	4	5	6
A	85	1	51	—	85	—	—	7	2	1	2	1	1	1
B	80	2-3	—	54	—	—	90	4	8	5	5	5	5	5
C	80	2-3	—	—	80	93	—	1	1	2	1	2	2	2
D	75	4	—	56	—	—	89	3	7	3	4	4	4	4
E	70	5-7	47	57	—	—	—	9	3	4	3	3	3	3
F	70	5-7	—	—	70	70	—	5	4	7	7	7	8	8
G	70	5-7	—	—	—	81	83	2	6	6	6	6	6	6
H	65	8	—	—	65	75	—	6	5	8	8	8	9	9
I	62	9	37	—	—	—	70	8	8	10	10	10	10	10
J	60	10	41	50	—	—	—	10	10	9	9	9	7	7

Science fairs are exciting. Teachers and students generally agree that they are worth every bit of the hard work that goes into them. But what about those students who choose not to do an independent science project? Chances are a student who is turned on to science by one of the nontraditional events described in this section will turn up later in the olympiads and other competitive programs. But the main advantage of these programs is they offer every student a chance to be a scientist, if only for a day.



Beyond the Science Fair

Biology, Chemistry, and Physics Are Team Sports

A science super bowl will be as exciting as the real thing and lots more educational.

by Charles W. Kellogg

Would you like your students to beg for outside readings in science or argue heatedly over the best way to determine the molecular weight of an unknown organic acid? Would you enjoy discussing recent advances in medical science or cosmology with gifted students, colleagues, and supervisors? If so, maybe there's a science league in your future.

The North Shore Science League in northeastern Massachusetts started in 1978 when I organized intramural biology competitions among teams selected from biology classes at Masconomet Regional High School. The competitions were so popular that I organized an interscholastic science competition. With a great deal of help from my colleagues at Masconomet and five or six science supervisors, we tackled our first meet in spring 1980. Now in its third year, the North Shore Science League, with teams from 14 schools, conducts 6 meets a year, each with more than 100 participants. The league combines the high frequency of meets in the Mathematics Leagues [2] with the hands-on, high interest team events of the Biology Olympics and Science Bowl [1, 3].

Take the field

The first two events at one of our meets usually are run simultaneously. One is a laboratory or field activity, for example, using a taxonomic key to identify biological specimens, naming minerals and fossils, or determining percent composition of an unknown chemical mixture. In the second event students solve problems: balancing chemical equations, sorting out Mendelian genetics, puzzling out mechanics, and more. The third event is a quiz similar to *College Bowl*. Although fun and exciting, the bowl is the most difficult to organize, judge, and score. Sometimes we resort to a written quiz instead. Topics have included space science, meteorology, recent advances in medicine, and environmental issues.

Several times we have added instant invention, a fourth event. Each team creates a device to perform a specified function. Once we required students to build a balance with plastic straws, string, paper clips, and tape. Students were then given several pennies of known mass and told to determine their mass. Finally, students had to measure out 50 g of water with their balance. The winning team came within 0.1 g. Although this event is very popular, we usually weigh it less in the scoring because of the somewhat unpredictable nature of the activities and the fact that luck rather than skill can often be an important factor.

We try for variety—in both subject matter and sophistication—in selecting topics for the meets. Life science, earth science, chemistry, and physics appear equally often over the course of a year, and at every meet we include at least one event in which first-year students can be successful. The activities we offer sometimes depend on whether or not special facilities are available. For example, one member school has a planetarium perfect for a laboratory event; another school lets us use its excellent fossil collection.

At the end of the day, we serve refreshments in the assembly room, and monitors begin scoring the events. To add to the excitement, we post the results immediately on an overhead projector. The winning team receives a trophy to keep until the next meet. The winner for the year has its school name engraved on the base of the trophy, which is a mug embellished with the number *1* and a medallion of Einstein. We fondly refer to it as the Einstein Award.

Ready for the kickoff

A great deal of planning and preparation is necessary for a successful meet. First, our constitution, adapted from that of the Tri-State Mathematics League [2], sets the guidelines for the meets. But even more important, we must keep devising new events. So far, teachers at member schools have contributed all the ideas, but it has been time-consuming. Currently, we offer $25 to anyone who submits an event that we use in the meets. (This comes out of the $50 membership dues paid by each school.) Many schools give stipends to their coaches. The president of the league is responsible for selecting the events for a particular meet. The host school also supplies the necessary staff, equipment, and facilities to run the meet as well as the

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refreshments. Since member schools have been very willing to sponsor meets, no school has had to stage more than one meet per year.

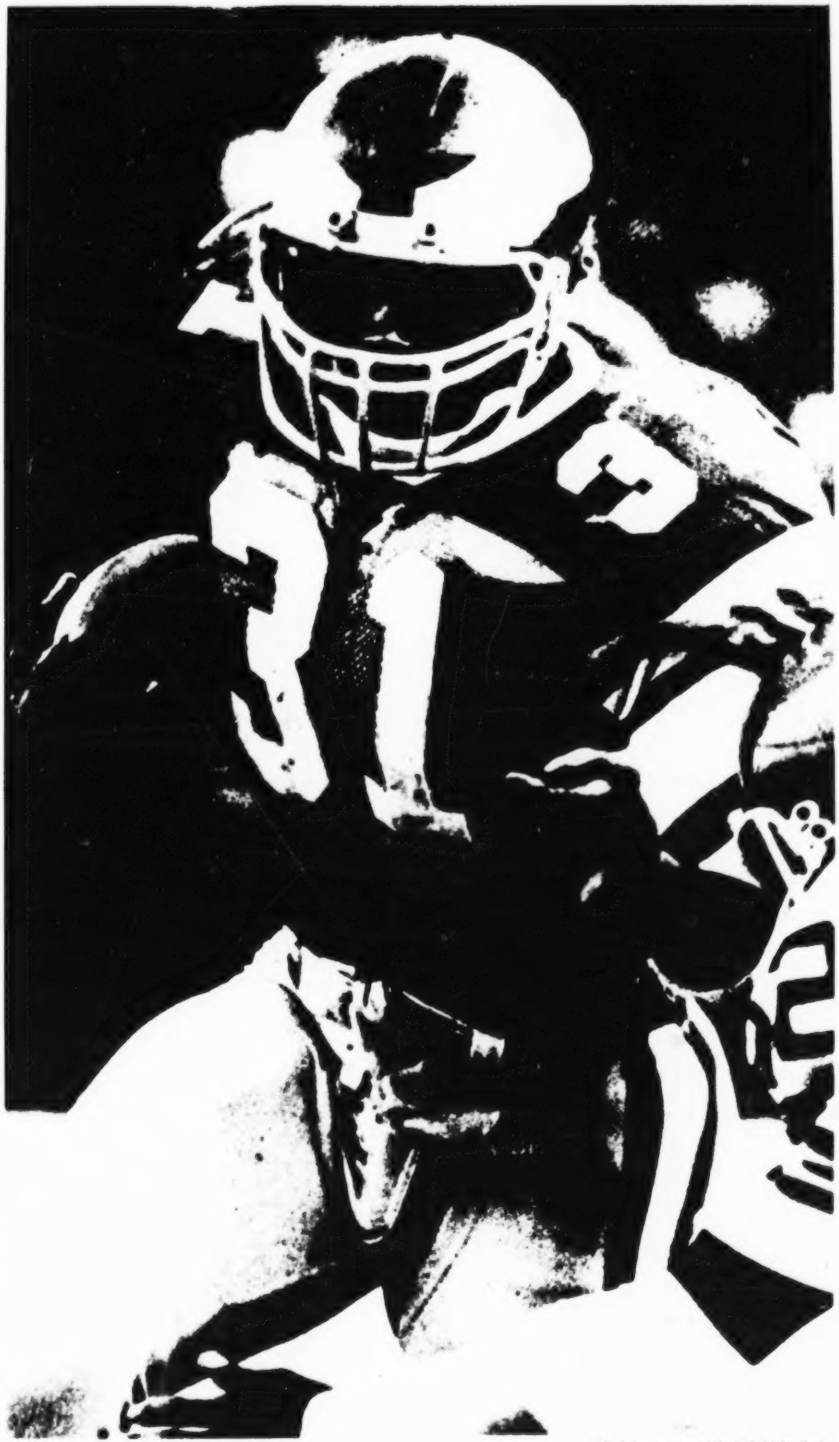
One warning: Once you have started a league, be prepared for your students to become highly competitive. They will eagerly await the announcements of the events for the next meet. They will demand practice sessions, which can be almost as much fun as the meet itself and are essential to a team performing well. For this reason, be sure to announce the topics for a meet well in advance.

We try not to limit the number of students who can join each team since diversity is a key ingredient for success; but we also try to have only 12 students from each school compete in each specialty at a meet. At the end of the year, we give school letters and other awards to all the participants at the annual Math-Science Banquet.

If you're beginning to think this sounds interesting, why not consider starting a league of your own? Begin by conducting an intramural competition at your school, as I did, among several classes. This will give you experience in organizing a meet and grab the attention of your students. After this, you'll be ready to organize a demonstration meet for several area schools, with a number of other schools invited to observe. This should spark plenty of interest. Take this opportunity to enlist faculty members from these schools to organize several future meets. Before long, the enthusiasm of both students and faculty will generate the momentum necessary for a formal Science League. The key to our success in founding the North Shore Science League was the commitment of many science supervisors and several teachers during the league's first 2 years. They volunteered to plan and run meets, design events, and even transport students when we did not have enough money for buses. Even though this was a lot of work, we all feel that it was worth the effort.

The Science League challenges and rewards students in a way normally reserved for athletes. The league has also fostered a greater sense of academic community among the faculty and students of member schools and has made our communities aware that academics is alive and well in the schools. Most important, however, students enjoy science—a feeling rarely experienced so strongly in the classroom.

I hope you now see a Science League in your future. I look forward to meeting you someday in the future NSL (National Science League) Super Bowl. May the best team win. Good luck! ■



—Ed Mahan, courtesy of the Philadelphia Eagles

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Editor's Corner

Science Olympiad

After an ebb of interest, student research is generating excitement again among teachers. We still have problems managing the fairs and integrating that work into our curricula, but more of us are deciding that it's well worth the time we spend on student research.

At the same time, a group of science educators is planning a totally new national program for student competition in the sciences—one that is both more lighthearted and more rigorous than traditional science fairs. This year, for the first time, students from all over the country will participate in the National Science Olympiad, a program that has already been quite successful in individual states. Aiming at making the national competition as rewarding as the local ones have become, Jack Cairns of Delaware and Gerald Putz of Michigan have spearheaded an intense effort to raise funds and to get people from across the nation involved in the olympics.

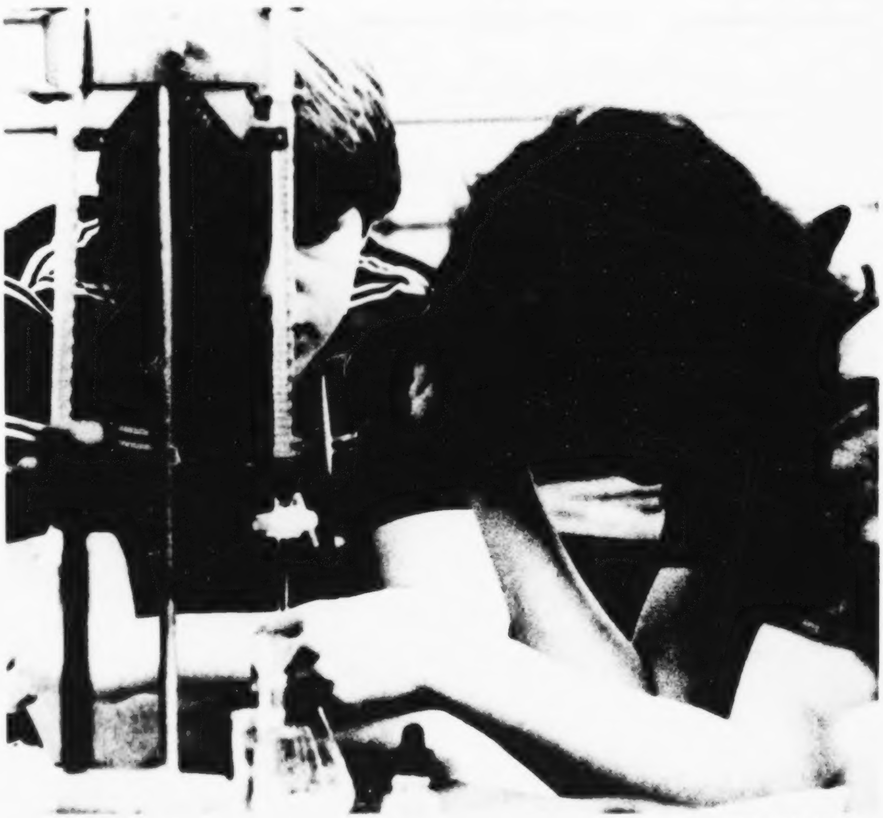
The Olympiad features team and individual events in junior high (grades 6 to 9) and senior high (grades 9 to 12) divisions. Challenges range from highly technical qualitative analysis, titration races, and computer programming to exciting and creative paper airplane contests, egg drops, and tea-making races. Activities that normally flower in quiet laboratories bloom to the cheers of fans and participants as spirited as those at any homecoming game.

Many state Olympiads climax their competitions with a Science Bowl, a trivia game of science facts that truly separates the amateur from the aficionado. The best competitors in these head-to-head rivalries are often not those with the highest grades or academic laurels. The Science Olympiad favors creative, self-motivated, independent thinkers—people with the traits that bode well for future Nobel Prizes. Team spirit and cooperation, the marks of good research groups, are the attitudes that produce winners in the team competitions.

Is it quantifiable?

Local Science Olympiad success is obvious: increasing attendance every year, higher enrollments in science classes, and more and more teachers volunteering their time and talents to make each olympics better than the last. As a veteran coach, I can attest that the contests are great occasions that keep getting greater. Students who never worried about grades became suddenly enthusiastic. Students "on the fringes" of the academic program were absorbed into the fervor of the events. I have fond memories of our years of state competition:

- the student who came directly



—Photos by Kathy Middleton

The Science Olympiad favors creative, independent thinkers—people with the traits that bode well for future Nobel Prizes.

from the senior prom, refusing to sleep until he took his medal in the catapult (trajectory) contest, and his successor, whose carefully made catapult fell apart as he demonstrated it for TV cameras before the event

- the end product of one session: a rocket that still sits on the roof of a local restaurant
- the senior who cried after receiving her gold medal in qualitative analysis—"the first award I ever got"
- the 10 days it took to regain full use of my vocal cords after cheering for our team.

Many educators and groups have endorsed the concept of the Science Olympiad. Otis Smith, Past President of the CAG Council, told state representatives, "What is really exciting is the prospect of having students of all ability levels involved in science." Past NSTA President Don McCurdy called the Olympiad "a vehicle for involving many students at the secondary level in scientific endeavors at a relatively low cost.

The Olympiad promises to involve a broad cross-section of business, industry, professional groups, and the general public in a productive effort to recognize students, teachers, and schools." At its July meeting, the NSTA Board of Directors unanimously endorsed the National Science Olympiad. Through the sponsorship of the United States Army, a national seminar for state facilitators took place this fall.

For information about the National Science Olympiad, write to Gerald Putz, 5955 Little Pine La., Rochester, MI 48064. Whether it's through a Science Olympiad, a science fair, the Space Shuttle Student Involvement Project, or another extracurricular activity, why not make this the year you challenge your students to go beyond the textbook? Share your successes and failures with other teachers and with NSTA. We'll all be glad you did. —*Juliana Texley*

Competing

Win or lose, when students work hard to prepare for these science contests, everyone wins.

The thrill of victory, the lessons learned from defeat—do they have a place in our science curricula? For many years contests and competitions were deemphasized, but today competition is making a comeback. Students and teachers alike attest to the motivational value of science fairs, symposia, and olympiads, all of them great motivators for students, whether or not you choose "winners."

And science teachers are discovering what the physical education department knew all along—that community support for programs is largely a function of public relations. Parents, friends, and boards of education all find ways to join in the action when science becomes a team sport.

What appears here are some suggestions of ways you and your students can become involved. Is a science team in your lesson plan?

Ready, Set, JETS!

by David J. Rowson

Opportunity often comes disguised as hardship. On certain Saturdays in February and March, thousands of high school students across the country prove that by taking rigorous 40-minute exams as part of the Junior Engineering Technical Society's (JETS) National TEAMS Competition. In pursuing the TEAMS challenge, students can win schoolwide, communitywide, and even nationwide recognition for academic excellence.

TEAMS (Tests of Engineering Aptitude, Mathematics, and Science) is a national academic interscholastic competition consisting of seven examinations: biology, chemistry, physics, mathematics, computer fundamentals, engineering graphics, and English—all the subjects in a college preparatory science curriculum.

Students who test in TEAMS get immediate rewards. TEAMS scoring takes place at the site of the competition immediately after the tests are completed. In a typical schedule, students compete in morning sessions, scores are tabulated, and winners are presented their awards as part of the same day's program. A TEAMS competition is an ideal occasion to emphasize college preparation, career guidance, and the fields of engineering, technology, math, and science. For example, a TEAMS competition can serve as the centerpiece for a day-long cluster of activities such as engineering or science exhibits, engineering design contests, or talks and panel discussions by people from business, industry, and academe.

Local recruits

Competition begins at the local level with sponsors who host competitions in their area, region, or state. Sponsors of TEAMS competitions come from local high school JETS chapters, area education units, professional engineering societies, and faculty at junior colleges and schools of engineering at leading universities. Sponsors recruit teams from area high schools; arrange for testing facilities; and form committees to proctor, score, arrange funding, and report results.

Local high school teams of up to 12 students each decide who will compete in each academic discipline. Each student is allowed to contribute only two exam scores to the point total, making TEAMS truly a team effort.

—University of Missouri

Local winning teams go on to the national TEAMS competition. At the close of the school year, TEAMS national winners receive their awards at an awards banquet in a prominent city. JETS provides award-winning teams and their coaches with expense-paid trips to the ceremony. The trip includes visits to local sites of technical or scientific interest. JETS presents national awards to the winners in each academic area and to the members of winning teams that represent schools having both large (700 or more) and small (fewer than 700) enrollments.

Help is available for anyone interested in holding a TEAMS competition. JETS state coordinators are responsible for all JETS activities in their state, so they contact JETS national headquarters on a regular basis. In addition, colleges of engineering and engineering societies such as the National Society of Professional Engineers, the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the Institute of Electrical and Electronics Engineers have consistently been willing to encourage and support TEAMS competitions.

The first back-to-back national champions in the small school category came from the community of Red Bud, Illinois (population 2600). At Red Bud High School, athletic and academic teams have equal stature. Just as the football and basketball teams are sent off with pep rallies, so are the members of the TEAMS team. Twice, in 1981 and 1982, they returned as national champions.

The TEAMS coach, Sandra Spalt,

See JETS page 52

David J. Rowson is associate director of JETS, 345 E. 47th St., New York, NY 10017. For more information on TEAMS competitions, contact him at that address or the JETS coordinator in your state.

Breakfast of Champions

by Marian McLeod

Science is alive and well and living at Seaholm High School! I wanted to shout it from the rooftops. Our team had just taken first place in the National Science Olympiad.

Everyone had worked hard and long. Winning had involved many more people than just the 15 team members. How could we prolong the heady feeling of victory and thank and honor everyone at the same time? We planned a Breakfast of Champions.

We invited the parents who loaned the family car, who wiped glue and supplied toothpicks (for bridge building), and who walked the woods with our orienteering champion. We didn't forget the retired rockhound who coached our geology champion, the doctor who lent out her professional library to our anatomy expert, and the astronomer who worked with our astronomy gold medalist.

And the teachers were there—not only the science teachers and department head who worked so hard, but the middle school teacher who helped our geologists and the industrial arts chairperson, who built an answer light system so we could practice Science Bowl. We welcomed the administrators, who gave unstinting support, and the department secretary, who never failed to lend a helping hand. Together with our champions, everyone shared in the satisfaction of a job well done.

The Science Olympiad brought excitement to our program at Seaholm. Our victory was significant with four gold medals, six silver medals, and one bronze.

Marian McLeod is an applied science teacher at Seaholm High School, 2436 W. Lincoln Rd., Birmingham, MI 48009.

For more information about the National Science Olympiad, see the November 1984 issue of *TST*, pages 8–9. To participate, contact your state science supervisor or Gerald Putz, 5955 Little Pine La., Rochester, MI 48064.

JETS

Continued from page 51

says Red Bud has no more talented students than other schools but points out that Red Bud students set reasonable goals and work hard to achieve them. Activity begins on freshman "farm teams," so depth is built into the team. Practices begin in October and are scheduled before, during, and after school hours.

The rewards from the years of hard work, in addition to the medals, trophies, and trips, are higher ACT and SAT scores, many scholarships, and the knowledge that some students have gone on to college who may otherwise have chosen not to. The career Red Bud winners most often pick? Engineering, of course.

A Competitions Sampler

Junior Science and Humanities Symposium

At the Junior Science and Humanities Symposium the emphasis is as much on sharing as on doing science. The program is modeled after professional scientific symposia; students present the results of their independent research orally in a competition that is as much forensic as scientific. Students also hear researchers and scientists who discuss the latest developments in their fields.

At 45 regional symposia, hosted by universities, panels of scientists hear the research of students nominated by their science teachers. The scientists select five representatives to the national meeting, which has been held at West Point, New York, in recent years. The program, which is free to students, is funded by the Army Research Office. For information, contact Barbara Osborne, Academy of Applied Sciences, Junior Science and Humanities Symposium, 4603 Western Blvd., Raleigh, NC 27606; (919) 851-1776.

Scholarships for the Inventive

The Annual Thomas Edison/Max McGraw Scholarship Program awards scholarships to high school students who are interested in science and engineering and who demonstrate the inventive genius of Thomas Alva Edison and Max McGraw.

All high school students in grades 9–12 who attend public, private, or parochial school in the United States, Canada, or other participating nation are eligible. To enter, a student must submit a proposal, which may be an abstract of an already completed experiment or a projected idea, on a practical application of an experiment in science or engineering. A letter of recommendation from the student's teacher or sponsor, which indicates how the student best exemplifies Edison's and McGraw's creativity and ingenuity, must accompany the proposal.

The 1986 awards will include two $5000 and ten $1000 scholarships. Proposals and letters of recommendation must be postmarked by *December 1st* each year. For information about next year's program, write to Robert A. Dean, PO Box 80953, San Diego, CA 92138.

Young Inventors

In the footsteps of DaVinci and Edison, today's young scientists are encouraged to invent in the annual Duracell Scholarship Competition. The reward: $30,000 in scholarship monies, and the satisfaction that comes with successful technology. Science is no vague endeavor for Duracell competitors; it is as real as lighted sneakers and battery-powered wind speed analyzers. Several of the teacher/sponsors of last year's competition wrote to *The Science Teacher*:

High emotions

There are moments in the lives of teachers that are charged with high emotions, when our hearts swell with pride and the glow of love seems to shine the brightest; such moments occur slowly if one is counting the years in the profession, but when the time comes, it is exhilarating. You suddenly realize that your dedication, patience, compassion, and meticulousness pay off.

Young Chris Urban brought about just such a moment in my life this year through his achievement—second-place winner of a Duracell scholarship.
—John Paul Rieck, science chairperson and teacher, Vineland High School, Vineland, N.J.

Solar tracking

Last year in the fall I received a brochure describing a competition sponsored by Duracell. The criterion here was creativity, and for the first time, I saw a program that was designed to help and even encourage the gifted, creative group. After announcing the event to my class, a student approached me and wanted to enter. We discussed the feasibility of making a solar tracking device, and he seemed very astute regarding its construction.

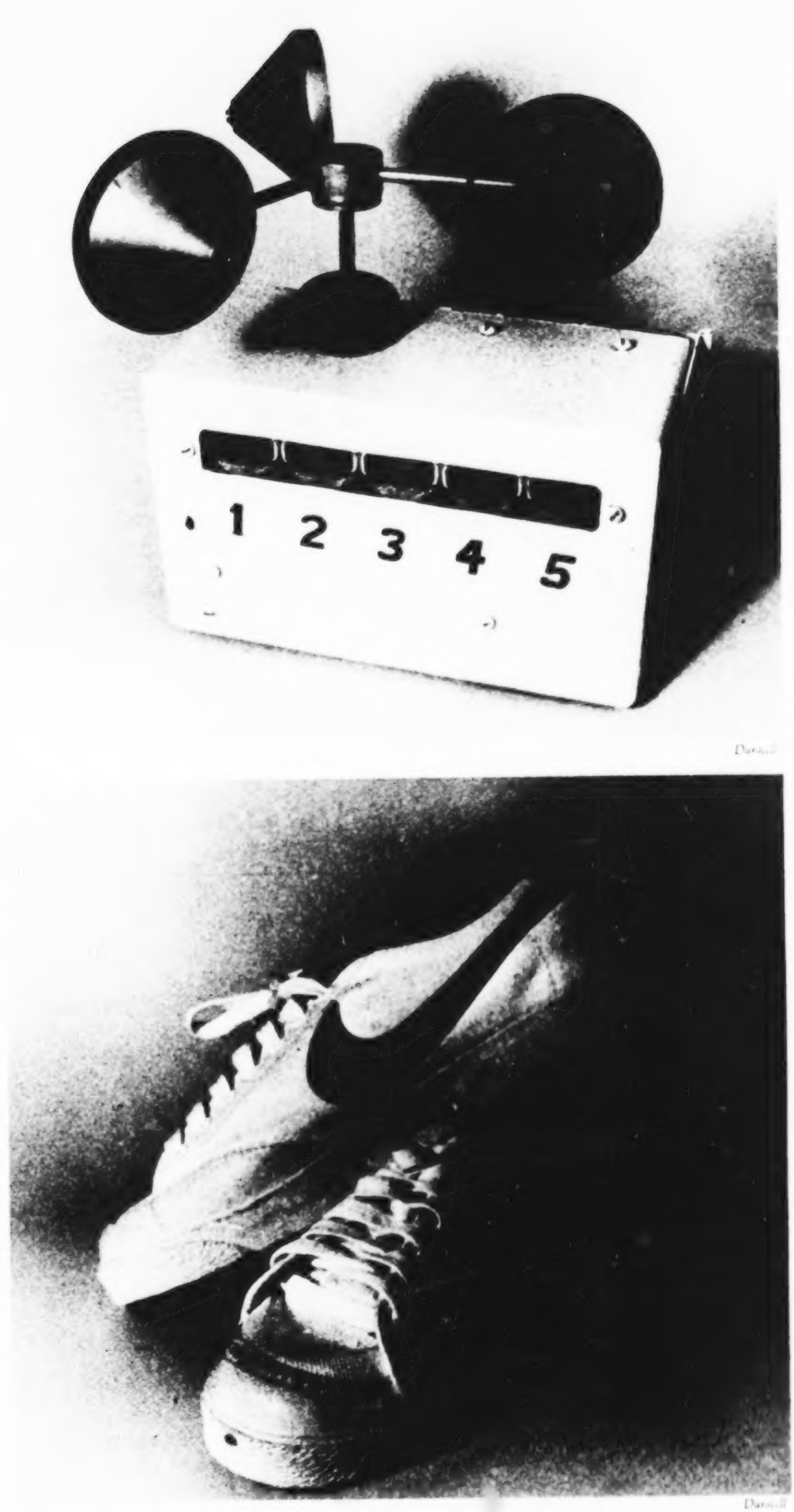
I was astonished, though, when he later brought the completed device to me in actual operating condition. The device won him second place in the competition and a $3000 scholarship. After this, I realized that there is indeed no limit to the potential of our youngsters.
—Jafar Naqvi, science teacher of second-place winner David Wilkins, Rocky Mountain High School, Fort Collins, Colo.

Laughing and cheering

From the first application to the final awards, I was excited, laughing, cheering, and just plain having fun. I sincerely believe the enthusiasm that the contest generated in me spilled over into my teaching, and that in turn influenced my students' efforts in the competition. I was able to show them the excitement of science in a way I could not in the classroom.
—Bob Saville, science teacher of second-prize winner Angus Calder and fourth-prize winner Eric Romeo, Shoreham Wading River High School, Shoreham, N.Y.

Independent study

A longstanding interest in alternative sources of energy and their potential application at our home in central Washington prompted my son Randy to design and construct a recording anemometer to aid in determining the feasibility of our site for a wind-powered generator. He chose this as



Duracell

Duracell

Randall Makela won the grand prize for "The Wind Speed Analyzer" (top) *and Christopher Urban won second place for "Lighted Sneakers"* (bottom) *in the 1985 Duracell Scholarship Competition.*

the problem to research and develop in an independent study course I offer to serious senior science students each year and to enter it in the Duracell competition.

Duracell administers the program in an excellent fashion from beginning to end. The guidelines are clear, concise, and unrestrictive. The experience was outstanding for all concerned.
—*George A. Makela, science teacher and father of the grand-prize winner, Cashmere High School, Cashmere, Wash.*

This year's entries in the Fourth Annual Duracell $30,000 Scholarship Competition are due *February 24, 1986*, and should be sent to Duracell Scholarship Competition, PO Box 812, Cooper Station, New York, NY 10276. For an official entry package, write to Duracell Scholarship Competition Entry Forms, PO Box 14312, Dayton, OH 45414.

Westinghouse Science Talent Search

Forty-four years of success are behind Westinghouse's effort to identify the most creative future scientists, engineers, and mathematicians. The program's alumni include five Nobel prize winners.

Students must submit the results of independent research and resumes by *December 15th* each year. For information about next year's program, contact Science Service, 1719 N St. NW, Washington, DC 20036. This year's awards will include $140,000 in scholarships and 40 all-expense-paid trips to Washington for the Science Talent Institute.

Space Shuttle Student Involvement Project

Now in its sixth year, the Space Shuttle Student Involvement Project (SSIP) offers high school students the chance to propose experiments that could be performed aboard the Space Shuttle. Past winners have proposed studies of crystal formation; silkworm, bee, and earthworm behavior; and plant growth, among others.

Kay Meisch, a chemistry teacher at Webster Senior High School, in Webster, New York, was advisor to 1984–1985 national winner John Nash. John won for his project "Effects of Gravity and Magnetic Field Strength on the Surface Morphology of Ferrofluids."

Ruth Magers

Thomas Walter, one of the seven SSIP winners for his project, "Reproduction in Space: An Investigation of Differences in Early Pattern Formation of Isolecithal (Echinoderm) and Mesolecithal (Amphibian) Eggs in Micro-g."

Meisch recalls, "My student was among the 7 national winners, selected from almost 3000. We were off to a launch!

"On Friday, August 23, 1985, our bus departed from Cocoa Beach for the Kennedy Space Center. We were welcomed by NASA officials and participated in a workshop.

"Our students each gave a 10- to 15-minute presentation about their project. That afternoon we toured Spaceport USA. An evening banquet and awards ceremony was led by Gerald Skoog, NSTA president, and Curtis Graves, acting director for educational affairs for NASA.

"Saturday morning we arose at 4:30 to go to the launch site, but thunderstorms delayed *Discovery*'s maiden voyage. Sunday morning it was 5:30, but again the countdown was stopped. A computer problem, and the second launch was scrapped.

"Helenmarie Hofman, of NSTA, came to everyone's rescue. NSTA would be our host until Tuesday. At 3:30 AM Tuesday it was raining and our prospects seemed gloomy. But the count continued, and our twice-delayed Shuttle thundered off the launchpad at 6:58 AM.

"Every minute we spent waiting was well worth it. It was one of the most exciting moments of our lives. John and I were very grateful for our unusual experience."

Students should describe their space experiment in a 1000-word proposal prepared according to SSIP guidelines, which were on the poster inserted in the September 1985 issue of *TST* and now are available from NSTA.

Regional winners and their advisors will attend expense-paid symposia at NASA centers next spring. National winners and their advisors will attend an expense-paid national symposium next summer. The three top students will receive scholarships from NSTA.

Any student in a U.S. public, private, parochial, or overseas school in grades 9 to 12 can enter. ■

one. We wanted to have a real fair in the county fair sense with events and activities in addition to the typical ISEF research competition. But first, our event needed a name. We couldn't use *science fair* because too many people, we thought, associated those words with unpleasant competition. So, after much discussion, we called the 3-day event the Northwest Science Exposition.

Brainstorming produced plans for a series of events. First, we would have a research competition, affiliated with the ISEF and run according to its rules and format. We called it a research competition to stress that it was only one part of the overall exposition.

We also arranged a noncompetitive display of student projects at the Oregon Museum of Science and Industry (OMSI). Many students, especially younger students, we decided, would rather exhibit their work and receive recognition for it in a noncompetitive, unjudged forum. Students could display research, but we also encouraged other kinds of projects—familiar models and demonstrations of well-known scientific principles as well as more creative science-art projects and diaries of nature trails. Originally, we thought this event would attract mostly middle schoolers, but we soon found that a significant number of high schoolers, including many who had done bona fide "competitive" research projects, opted to exhibit their work at the noncompetitive show.

In our third event, an "olympics," teams of students challenged one another in the high school science big three: biology, chemistry, and physics. Each of the olympics began with a quiz in which every team took a written test. Team members cooperated in answering the items. Then the top four teams competed in a college-bowl-type verbal quiz. Except for the quiz bowl, each olympic event was unique. I describe some of them in the box accompanying this article.

We also arranged a series of tours

—Kathy Middleton

—Kathy Middleton

to sites of scientific interest, including the Washington Park Zoo (students got to go "backstage" as well as view the animals out front), the Oregon Graduate Center (various research labs), the Regional Primate Research Center (research labs and a Macaque colony), CH2MHill Civil Engineering firm, and the National Weather Service.

Finally, students could sign up for workshops at OMSI in forensic science, microbial genetics, computer flight simulation, and computer graphics and music. One day at the exposition, Astronomy Day, featured an OMSI planetarium educator offering workshops and shows. Some students opted to see videotapes from the *Voyager* missions.

In addition, the Lane County (Oregon) Educational Service District provided a portable planetarium, and students and teachers could attend science films during the day at OMSI. To avoid the problem of students having nothing to do on Friday night and to promote social interaction among students from the different schools, we scheduled a barbecue, a physics demonstration, and a dance, complete with a very live band.

Putting on this extravaganza posed a number of problems and required the close cooperation of many groups of people. Fortunately, the Expo was sponsored by a consortium including the Oregon Science Teachers Association (OSTA), the Portland section of the American Chemical Society (ACS), the Oregon section of the American Association of Physics Teachers (AAPT), the Northwest Association of Marine Educators (NAME), the

At the starting line

Step right up and try your luck at the fair with these team competitions. Your students may not come up with a kewpie doll for their efforts, but they will have every bit as much fun at these science fair activities as they would at the county fair. And they may learn a bit of science, too.

- ***Biology charades.*** **Each four-student team uses one demonstrator and three interpreters to demonstrate as many randomly drawn biological terms as possible in 30 min.**
- ***Acid titration.*** **Each team determines the equivalent weight of an unknown solid acid using a buret and a standardized base solution the team brings to the Expo.**
- ***Ethanol purification.*** **Given a 125-mL aqueous solution of ethanol, each team prepares a 50-mL sample of ethanol. Award prizes based on proof. In our competition a group of eighth graders enrolled in IPS beat a group of high school students.**
- ***Maximum density of an aqueous solution.*** **Each team brings its own solid. Have the teams exchange solids and then make solutions with deionized water you provide. After 20 min., teams filter their solutions and determine density with a hydrometer.**
- ***Qualitative analysis.*** **Give each team seven numbered test tubes, each containing an unknown cation. Teams must identify the ions.**
- ***Paper airplane time of flight.*** **Each team designs paper airplanes according to rules available before the olympics. Add times of flight for each team's planes; the highest team total wins.**
- ***Laser shoot.*** **Place a HeNe laser 1 m from a semicircular dish of water. Place a target on the other side of the dish and 6 m from the laser. Each team must figure the angle of refraction and predict the position of the laser beam on the target for a given angle of the semicircular dish.**

—W. L/P. B.

William G. Lamb teaches chemistry and physics at Oregon Episcopal School, 6300 S.W. Nicol Rd., Portland, OR 97223. Peter Brown is a teaching associate at the Oregon Museum of Science and Industry, 4015 S.W. Canyon Rd., Portland, OR 97221.

Oregon State Department of Education, and the Oregon Museum of Science and Industry. This cross-fertilization has been important because, although many of the same teachers belong to OSTA and NAME, there is very little overlap among OSTA, ACS, and AAPT. Although the Expo would probably have been easier to stage with fewer interests represented and a well-financed dictator delegating the tasks, the give-and-take of planning meetings and our mutual delight in finally executing the Expo helped all of us build vital professional networks.

Coordinating so many activities at three sites separated by several kilometers proved to be pretty challenging, but came off with only a few hitches. We arranged for shuttle bus service between the sites. Except for students who tried to take part in both the research competition (which ran a little ahead of schedule) and the olympics (which ran a little behind schedule), most students got where they wanted to go on time.

In its first year, the Expo served 33 schools and more than 500 students. Most schools participated in a variety of the activities. More than 60 percent of the teachers returned a questionnaire evaluating the Expo. The general consensus? The Expo was just dandy and would have been dandier with better organization.

We're quite proud of our first annual Expo, which was supported by generous grants from the Swindells Fund of the Oregon Community Foundation and the Winningstad Chair Fund of the Oregon Episcopal School. We look forward to the next, which will be held in Hillsboro (Oregon) High School, April 12–13, 1985. We are especially happy that all the major events will be at one site. It's the combination of individual research and team competition, noncompetitive exhibits, films, tours, workshops, and social events that makes the Northwest Science Exposition a real science *fair*. ■

Pointing the Way for Young Researchers

by Lynn W. Glass

Sometimes students have a hard time sifting through the rules of a science fair to come up with a project that pleases both the judges and themselves. Here in Iowa, a strong support organization guides students through their early days in research. From before project planning to the national meeting of the American Junior Academy of Science, the Iowa Junior Academy of Science backs its young researchers.

Each fall the Iowa Junior Academy conducts a "how to" workshop for high school students and teachers who are interested in getting a science research project started. The workshop helps students define a manageable research topic, locate resources (both people and print), and learn how to present findings. Other teachers and successful student researchers run the workshops.

We then introduce the young scientists to a skill that will come in quite handy if they go on in research: writing research grant proposals. We encourage all Iowa secondary school students to complete a two-page grant application form, and we award research support of up to $200 for a project.

Science students in Iowa seem to be always busy—at science fairs, science symposia, science olympics, university research participation projects, and various other science competitions. The Iowa Junior Academy of Science publicizes these events and recognizes the winners. At its annual meeting, the Iowa Academy of Science highlights award-winning students from the many state science events of the preceding year. In addition, the director of each event nominates a select few students to compete for our Junior Academy's highest honor—two expense-paid trips to the annual meetings of the American Association for the Advancement of Science and the American Junior Academy of Science. The students vie for the awards by presenting a poster paper and oral research report. The governor of Iowa usually comes to honor all these deserving students.

The 1983–1984 school year marked the first annual Outstanding Science Student Award program sponsored by the Iowa Junior Academy of Science and the Iowa Academy of Science. Nearly 400 senior students from 500 Iowa high schools received a bronze medallion for their excellence in science.

We're also excited about our first amusement park physics project this fall. More than 2000 junior high students are learning about physics while having fun on 12 different amusement park rides. Plans are currently underway to expand this popular event to include even more students next fall.

Funding for our many events and activities comes from three sources. Private enterprise covers a large portion of our expenses. A competitive grant from the American Association for the Advancement of Science pays about half of our student research grant program. Dues and other sources of income to the Iowa Academy of Science are the third source of support for the Junior Academy.

We like to think of the Iowa Junior Academy of Science as a training ground for a new generation of scientists. Don't be surprised if a disproportionate number of the next crop of Nobel laureates in science hail from the Hawkeye State. ■

Lynn W. Glass directs the Iowa Junior Academy of Science and is a professor of secondary education, N156 Quadrangle, Iowa State University, Ames, IA 50011.

Consumer Fair: A Cure for the Science Fair Blues

Spring should be a time of rejuvenated optimism, renewed vigor, and hearty self-congratulation upon successfully surviving another winter. However, in classrooms across the nation, science teachers are faced with the seasonal malady known as Science Fair Syndrome (SFS). The victims of SFS often complain of low student motivational levels, high incidences of uncontrolled variables, and hallucinatory visions of papier-mache volcanoes. If you share these symptoms, why not try a consumer fair as an alternative to a traditional science fair?

The basic premise of the consumer fair is that we are all purchasers of goods and services. From the toddler begging for a penny for the gumball machine to an adult making a decision on the purchase of a cemetery plot, the acquisition and spending of money is a basic fact of life. Our economy encourages consumption by young people, but often these young consumers do not have the skills and knowledge necessary to buy wisely. Consumer fair projects encourage students to use scientific investigation skills learned in the classroom as a means to becoming more independent and intelligent consumers.

In the consumer fair scheme, the students are led through a series of steps to arrive at their own choice of project topic and investigation. The first step is a visit to the neighborhood grocery store with its variety of grocery and other consumer products. The students list ten foods and ten non-food products and three brands of each product on a form which I provide. They then narrow down their list of products until they have chosen the one product of greatest interest to them. This single product represented by three different brands for the purposes of comparison becomes the subject of their project. Next students decide which of the many aspects of their product they wish to investigate. The aspects might include: weight, volume, number of items, packaging, effectiveness, or taste. Their final step in this preliminary stage is to formulate a question (hypothesis) about the aspect they will use to compare the three product brands. An example of an investigative question is: Which brand of diaper, brand X, Y, or Z, actually absorbs the most moisture?

Students use the scientific method to search for answers. Consumer projects offer the opportunity for them to construct a hypothesis from a question, identify and control variables, design and conduct an experiment, and collect and analyze data (see Figure 1). Students often need assistance as they develop their experimental design. During this phase, the teacher serves as resource

Figure 1: Investigation Set-Up Sheet

Product Investigated: ______________

____

Three Brands Compared: ______________

____

Question about Product to be

Answered: ______________

____

1. **Hypothesis:**
2. **Manipulated Variable:**
3. **Responding Variable:**
4. **Controlled Variable:**
5. **Equipment:**
6. **Procedure:**
7. **Data Collected:**
8. **Hypothesis Check:**
9. **Conclusion:**

person and facilitator, answering questions and offering advice. The actual experiments may be conducted in or out of class. While some experiments require equipment and the use of process and measuring skills, others such as blind tests for taste preference, emphasize the use of subjects and proper sampling and control techniques.

In addition to the data gathered during their experiments, the students also compare the tested brands by doing a cost analysis (Figure 2). They compare the three brands using one quantitative aspect, such as volume, weight, or number of items, divided into each brand's cost. The resulting per unit cost is used to determine which brand is the best buy.

The students bring experimental data they collect in the form of graphs, charts, conclusions, and experimental procedures on posters. The posters, the three brands of the product used for comparison, and the materials used to conduct the experiment are combined as a display. These displays make up the consumer fair. Teachers evaluate the projects according to the scoring criteria in Figure 3.

Consumer fairs are educational, interesting, motivating, and fun. The activities provide reinforcement of skills taught in the science classroom and help students become knowledgeable and independent consumers. Most important, consumer fairs illustrate that science and the methods of science are relevant to students' everyday lives.

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Rock Island, Illinois

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Figure 2: Cost Analysis

When comparing several brands of the same product, a consumer is often interested in which is the "best buy." You can figure any relative costs of several brands of the same product by doing a *cost analysis*.

Directions: You first decide on one aspect of the product that you will use to compare all the brands. You should use *volume, weight,* or *number of items* for this comparison. Then fill in the chart below using the brands you are comparing.

	Brands	Cost	Volume, Weight, or Number of Items
1.			
2.			
3.			

You will need to do some dividing. Divide the cost of the brand into its volume, weight, or number of items to find the *per unit cost* for each of your brands. The *per unit cost* tells you how much product you get for one cent. Use the formula below to help.

$$\begin{array}{r}\text{Per Unit Cost}\\ \text{Cost}\ \overline{\big)\ \text{Volume, Weight, or No. of Items}}\end{array}$$

Repeat the procedure for all the brands being compared. Then fill in the chart below to identify which brand is the best buy.

	Brand	Per Unit Cost	Best Buy
1.			
2.			
3.			

Figure 3: Project Scoresheet

_____ 1-5 A) **Project Set-Up**
- Question investigated well thought out
- Investigation procedure well designed
- Investigation followed as designed

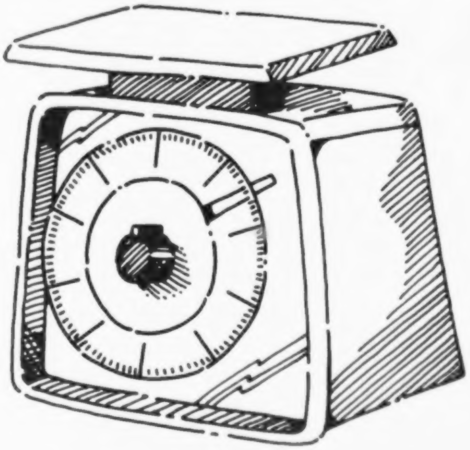
_____ 1-5 B) **Project Results**
- Quality data collected
- Hypothesis check supported by data
- Data displayed using charts or graphs
- Conclusions made from data clearly stated

_____ 1-5 C) **Project Appearance**
- Posters complete and neatly printed
- Display well organized
- Display informative and understandable
- Product brands displayed

_____ 1-5 D) **Brand-Cost Analysis**
- Brands correctly compared
- Correct calculations
- Best buy data clearly charted or graphed

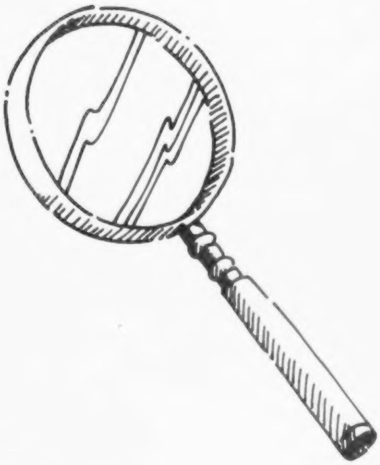
_____ 1-5 E) **Project Effort**
- Project complete and on time

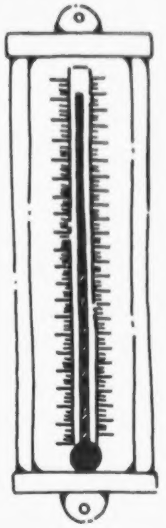
_____ 5-25 = **Total Score** **1st Place** = 23-25 points, **2nd place** = 20-22 points
3rd Place = 17-19 points, **4th place** = 14-16 points

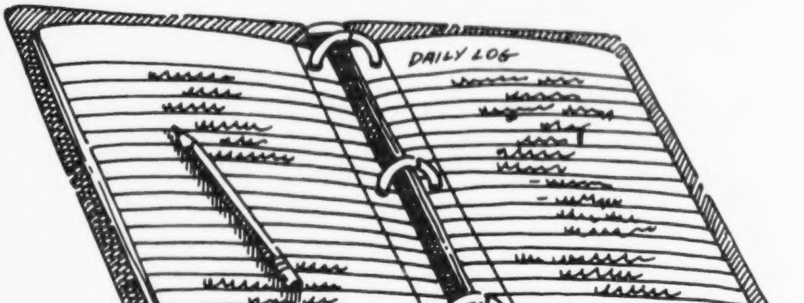


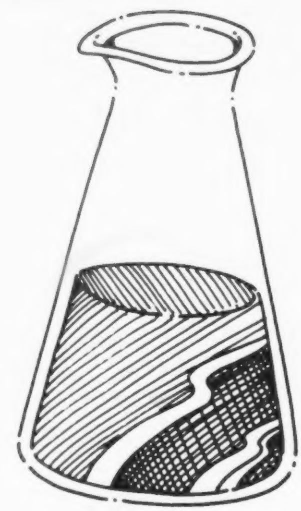
Appendix

Notes to parents, schedules for students, instructions to judges are the keystones science fair organizers rely upon. We've collected these forms for you to use as is, or to modify to meet your program's special needs. Most of these forms were originally produced by Ed Donovan of the School of Education, University of South Carolina, Spartansburg. We hope they will help you create the best science fair ever.









Science Fair Project Application

Name ______________________________ Date ______________

Teacher ______________________________ Grade ______________

Project Title ____

Project Description (be brief) ______________________________

____

____

PROJECT AREA (circle one):

Biology Chemistry Physics Mathematics Behavioral General Science

PROJECT TYPE (check one):

_______ ***Experimental***—Forming a hypothesis (question) about something the student doesn't know the answer to, doing an actual scientific experiment, making observations, collecting data, and reaching conclusions.

_______ ***Demonstration***—Science in a show and tell format. The student knows what is going to happen when he or she begins. Includes models, kits, collections, posters, etc.

_______ ***Biological***—A project involving living things such as insects, birds, food, people, diseases, etc.

_______ ***Physical***—A project involving things not living such as chemicals, stars, air pressure, weather, etc.

Will you require electricity? _____ YES _____ NO

Your project should include the following items:

1. Exhibit that can stand by itself.
2. Research paper with bibliography.
3. Abstract (one page summary, with bibliography).
4. Materials necessary for the exhibit.
5. Oral presentation (3 to 5 minutes).
6. Logbook of daily work.

Return this completed form to your teacher by ______________________________

Student signature ______________________________

Parent's signature ______________________________

Teacher's signature ______________________________

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Information for Students About Science Fair Projects

A Successful Science Project:

1. Represents your work—not that of an expert or your parents
2. Indicates an understanding of the science area chosen
3. Shows careful planning that would eliminate a "rush" project
4. Has a notebook showing a complete record of all your work
5. Has a simple, well-stated title and neat lettering
6. Includes photographs, charts, pictures, graphs, etc., that might be necessary to explain your work
7. Has accurate, valid, and correct observations
8. Tells a complete story—Problem and Solution
9. Is original in approach and presentation
10. Is self-explanatory
11. Is attractive and organized
12. Does not have to cost much money
13. Is best if it is an experiment, but it doesn't have to be
14. Is one that gives credit to those who gave help

A Science Fair Project is Not:

1. Only a report
2. Necessarily a new discovery or an original piece of research
3. Constructing a plastic model from a hobby kit
4. An enlarged model or drawing
5. A week-end chore
6. One, two, or even three posters
7. Something done by your parents or teacher

Steps in Making a Science Project:

1. Choose a topic and discuss it with your teacher. Ask your teacher for help and suggestions.
2. Once you have chosen your topic problem, find out as much about the topic a possible.
3. Keep a project notebook and record all of your thought, preparations, and ideas. Keep a record of your readings.
4. Set up a work area somewhere around your house where you can work on your project. Make sure the area is off limits to your pets or younger brothers and sisters.
5. Work on your project a little each day, don't wait until the last minute.
6. Collect the materials needed for the project.
7. Check with your teacher for suggestions and materials, he or she can save you time, excess, work, and money.
8. Construct your exhibit and make letters for your signs.
9. Mount your pictures, graphs, charts, etc.
10. Present your science project at the fair.

Created by Becky Brown, Chapman Elementary School, Spartanburg School District #7, Spartanburg, South Carolina
Modified by Ed Donovan, Science Education Center, School of Education, University of South Carolina, Spartanburg

Schedule for the Student's Science Fair Project

Week	What You Should Be Working On	Due Date	Check ✓
1	* Make sure you understand what you need to do for the science fair project. Ask questions if you're not certain about any aspect of the assignment. * Find time to use books, encyclopedias, and magazines at the library. Look for a topic that is interesting to you. Keep bibliographic notes on the books and magazine articles where you get your ideas. * You may want to visit museums, hospitals, universities, zoos, and science centers to get ideas.		
2	* With your project idea firmly in mind, write the purpose, question, hypothesis, materials needed, and procedures. * Show your written material to the teacher and discuss your project for approval.		
3	* After the science project has been approved by the science teacher, begin to gather your necessary equipment and begin your project.		
4	* Seek advice and help from professionals to refine your project: doctors, nurses, researchers, teachers, librarians, veterinarians.		
5	* Conduct your experiment and collect data. * Keep careful, written records of results in a notebook. Record the day and time you make observations. Be as specific as you can about the amount, size, and type of materials, plants, or animals you use.		
6	* Draw conclusion and organize the results of your experiments in chart or graph form.		
7	* Write your research paper. Include a table of contents, abstract, summary sheet, purpose or hypothesis, step-by-step explanation of your experiment, results, conclusion, and bibliography.		
8	* Construct your exhibit. Build a back-drop to mount graphs, charts, illustrations, photographs, signs, and summary sheets.		
9	* Prepare an oral presentation.		
10	* Add finishing touches to your project. * Come to the science fair and present your project.		

The Scientific Method

A student record sheet for an experiment or science project

1. What do you want to find out?
(PURPOSE)

2. What do you think will happen?
(HYPOTHESIS)

3. What do you need to use?
(MATERIALS)

4. What will you do to find out?
(PROCEDURES)

5. What happened?
(RESULTS)

6. What did you learn?
(CONCLUSIONS)

Note to Parents

We hope the following suggestions will be helpful as your child develops this year's science project:

1. Please remember that the most important ingredient in any project is the amount of work the student accomplishes, how much knowledge he or she acquires, and how much initiative is displayed. Many abilities are developed researching, organizing, outlining, measuring, calculating, reporting, and presenting. These involve the reading, writing, arithmetic, and social skills so much a part of successful daily living.

2. Although it is to be the student's effort, there is no substitute for a parent's support.

3. Do not worry about the project's performance at a science fair. If strengthened thinking skills and increased knowledge have occurred, then a prize has truly been won.

4. Areas in which a parent's assistance will be necessary include:
   a. *Safety.* Be sure that poisons, dangerous chemicals, and open fires are avoided. Learn and practice electrical safety if electricity is used in the project. If any aspect of the project appears to be dangerous, it is not to be included.
   b. *Transportation.* Help will be needed for the transportation of materials to the science fair, although it is better if the student can set up and take down the exhibit with a minimum of assistance.

5. Areas in which a parent's assistance may be welcome include:
   a. Suggesting project ideas (these may be connected with your work).
   b. Transportation to libraries, businesses, museums, nature centers, universities, or any source of project information.
   c. Technical work such as construction and photography.
   d. Being an interested listener.

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Science Fair Parent Volunteer Form

I would like to volunteer for the following jobs at the science fair:
(Check where you can help.)

______ Science Fair Committee

______ Help set up the gym

______ Help supply refreshments

______ Supervise students setting up

______ Supervise students during judging

______ Help clean up the gym

Name______________________________ Addresss______________________________

Telephone #______________________________ **PLEASE RETURN BY**______________________________

Helping Your Children with Their Science Fair Projects

Things a parent may do:

1. Give encouragement, support, and guidance. (Be positive!)
2. Make sure your child feels it is his or her project. Make sure the project is primarily the work of the child.
3. Realize that the main purpose of a science fair project is to help your child use and strengthen the basic skills he or she has learned and to develop higher level skills.
4. Realize your child will need help in understanding, acquiring, and using the major science process skills (researching, organizing, measuring, calculating, reporting, demonstrating, experimenting, collecting, constructing, presenting). Your child may not have been taught these skills. Therefore, it may not be fair to expect him or her to know how to do them.
5. Realize that your child may be using reading, writing, arithmetic, and social skills for the first time in a creative way to solve a problem.
6. Realize that the teacher works with 20-30 students and this may make it difficult to give a large amount of individual attention to your child.
7. Understand that the teacher may need your help. If you have the interest and the time, you might contact the teacher and volunteer to help or judge at the school's science fair.
8. Help your child plan a mutually agreed upon schedule, to prevent a last minute project and a disrupted household. A 4 to 8 week plan that uses a check-off sheet is best. The following steps (you may want to add more) should be on your schedule.
   a. find a topic.
   b. narrow down the topic to a specific scientific problem that is appropriate to the child's ability level.
   c. research what is already known about the problem.
   d. develop a hypothesis. (What outcome do you expect?)
   e. develop a procedure/investigation to test the hypothesis (if experimental).
   f. make observations and collecting appropriate data.
   g. interpret the data and other observations.
   h. state and display the results.
   i. draw appropriate conclusions.
   j. create the exhibit.
   k. write the research paper and the abstract.
   l. present the project.
9. Help your child design a safe project that is not hazardous in any way.
10. Provide transportation to such places as libraries, nature centers, universities, etc. that can help the child find project information.

11. Help your child write letters to people who can provide help on the science project and be sure the letters are mailed.
12. Help the child develop the necessary technical skills and/or help the child do the technical work such as building the exhibit and doing the photography.
13. Help your child understand that science is not a subject but a "way of looking at the world around us."
14. Be sure that the child states in the paper and/or exhibit the help he or she has received from you or others. This will help judges to make a fairer evaluation of the project.
15. Look over the project to check for good grammar, neatness, spelling, and accuracy. Make suggestions on how it can be corrected .
16. Buy or help find the necessary materials to complete the project.
17. Realize that a good project doesn't have to cost a lot of money. Many times a simple project that is well displayed and explained is the best.
18. Help the child understand that a weekend chore, or one or two posters, is not a project.
19. Help the child to keep a record (log book) of all he or she does and a list of references used.
20. Find an area in the house where the child can work on the project and not have to worry about pets or brothers and sisters.
21. Explain to the child that he or she should consult with you or the teacher when problems arise. Set aside time for help sessions. Make them short and constructive. Be an interested and enthusiastic listener.
22. Have your child present his or her science project to you before he or she takes it to school.
23. Help transport child and the science fair project to and from the school/district/regional science fairs.
24. Do not worry or get upset if your child doesn't win a prize at the science fair. The skills the child has gained are worth all of the effort. Help your child to begin to plan for next year.
25. Feel a sense of pride and satisfaction when the project and the science fair are finished. Share this with your child, you have both earned it.

Science Fair Project Judging Criteria

Scientific Thought (30 points)

Does the project follow the scientific method? (hypothesis, method, data, conclusion)
Is the problem clearly and concisely stated?
Are the procedures appropriate, organized, and thorough?
Is the information collected accurate and complete?
Does the study illustrate a controlled experiment that makes appropriate comparisons?
Are the variables clearly defined?
Are the conclusions accurate and based upon the results?
Does the project show the child is familiar with the topic?
Does the project represent real study and effort?

Creative Ability (30 points)

How unique is the project?
Does the exhibit show original thinking or a unique method or approach?
Is it significant and unusual for the age of the student?
Does the project demonstrate ideas arrived by the child?

Understanding (10 points)

Does it explain what the student learned about the topic?
Did the student use appropriate literature for research?
Is a list of references or bibliography available?
In the exhibit, did the student tell a complete and concise story, and answer some questions about the topic?

Clarity (10 points)

Did the student clearly communicate the nature of the problem, how the problem was solved, and the conclusions?
Are the problems, procedures, data, and conclusions presented clearly, and in a logical order?
Did the student clearly and accurately articulate in writing what was accomplished?
Is the objective of the project likely to be understood by one not trained in the subject area?

Dramatic Value (10 points)

How well did the student design and construct the exhibit?
Are all of the components of the project done well? (exhibit, paper, abstract, log of work)
Is the proper emphasis given to important ideas?
Is the display visually appealing?
Is attention sustained by the project and focused on the objective?

Technical Skill (10 points)

Was the majority of the work done by the student, and was it done at home or in school?
Does the project show effort and good craftsmanship by the student?
Has the student acknowledged help received from others?
Does the written material show attention to grammar and to spelling?
Is the project physically sound and durably constructed? Will it stand normal wear and tear?
Does the project stand by itself?

Science Fair Project Judging Form

Project Title ______________________ Project Number ______________________

Project Category ______________________ Judge Number ______________________

CRITERIA: *POINTS*

Scientific Thought (30 Points) ______

Is the problem concisely stated?
Are the procedures appropriate and thorough?
Is the information collected complete?
Are the conclusions reached accurate?
Comments:

Creativity (30 points) ______

How unique is the project?
Is it significant and unusual for the age of the student?
Does the project show ideas arrived by the student?
Comments:

Understanding (10 points) ______

What did the student learn about the project?
Did the student use appropriate literature for research?
Can the student answer questions about the topic?
Comments:

Clarity (10 points) ______

Are the problems, procedures, data, and conclusions presented logically?
Can the objective be understood by non-scientists?
Is the written material clear and articulate?
Comments:

Dramatic Value (10 points) ______

How well did the student present the project?
Is the display visually appealing?
Is the proper emphasis given to important ideas?
Comments:

Technical Skill (10 points) ______

Was the majority of the work done by the student?
Does the written material show attention to grammar and spelling?
Is the project well-constructed?
Comments:

TOTAL POINTS
(based upon 100) ______